Iron and Steel ENGINEER

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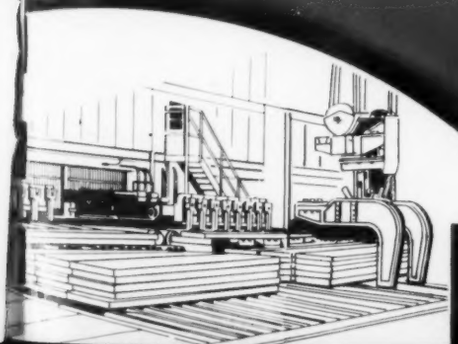

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The basic metals industry, like most industries, is always in a stage of development. New ideas and new products must be developed to stay ahead or even abreast. This means hard work, man-hours, and money.

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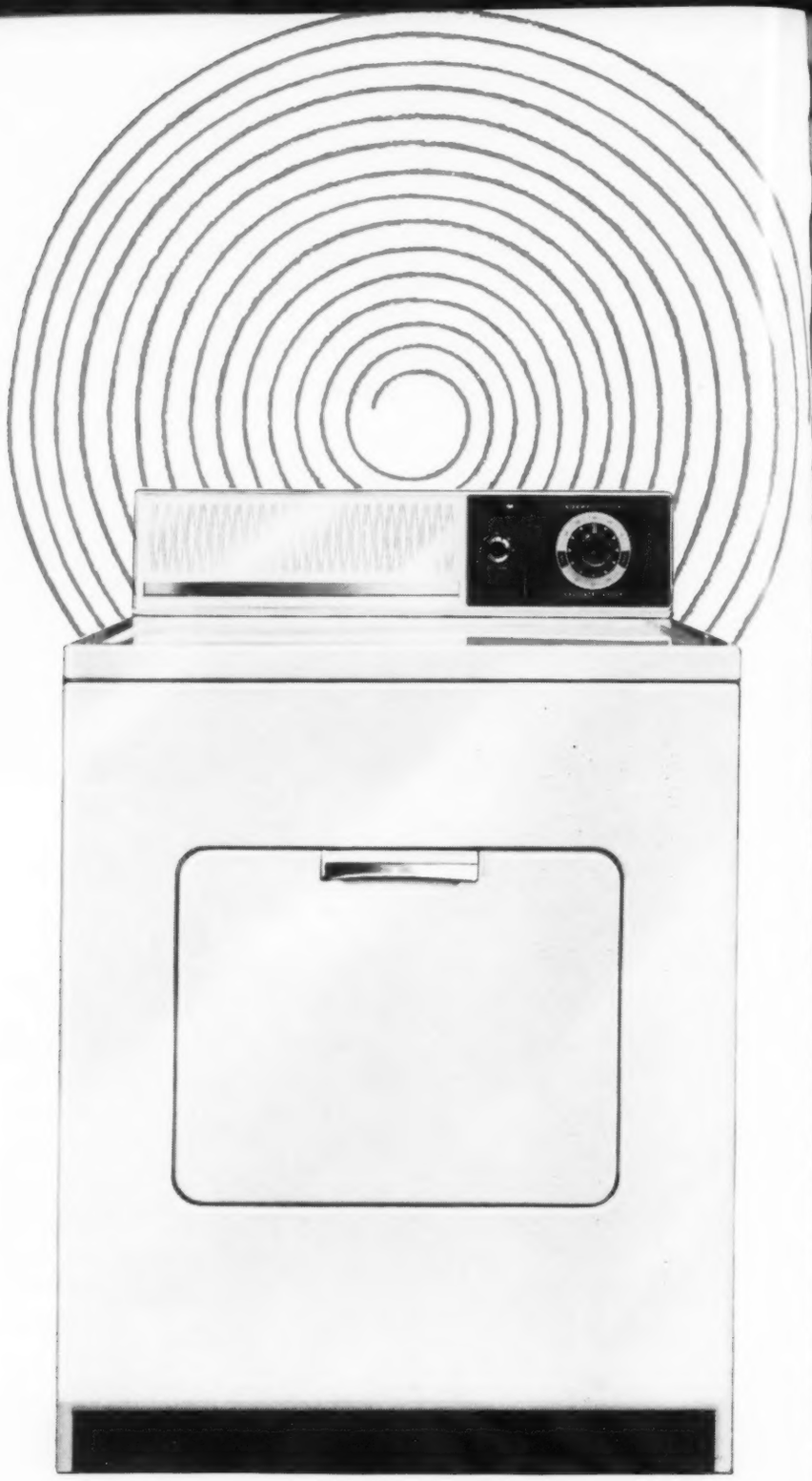

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Open up the steel coil and subject it to controlled gases, and you can produce commercial quantities of "direct-on" enameling steel from regular rimmed steel sheet. Here's an economic edge for both producer and user. Steelmakers no longer need supply low metalloid steels which are expensive to melt and roll, and the enameler can eliminate one of the two steps in his processing. To get all the details on this revolutionary new Open Coil Process of Gas Alloying write for Bulletin OC-960, *Lee Wilson Engineering Co., Inc., 20005 Lake Road, Cleveland 16, Ohio.*

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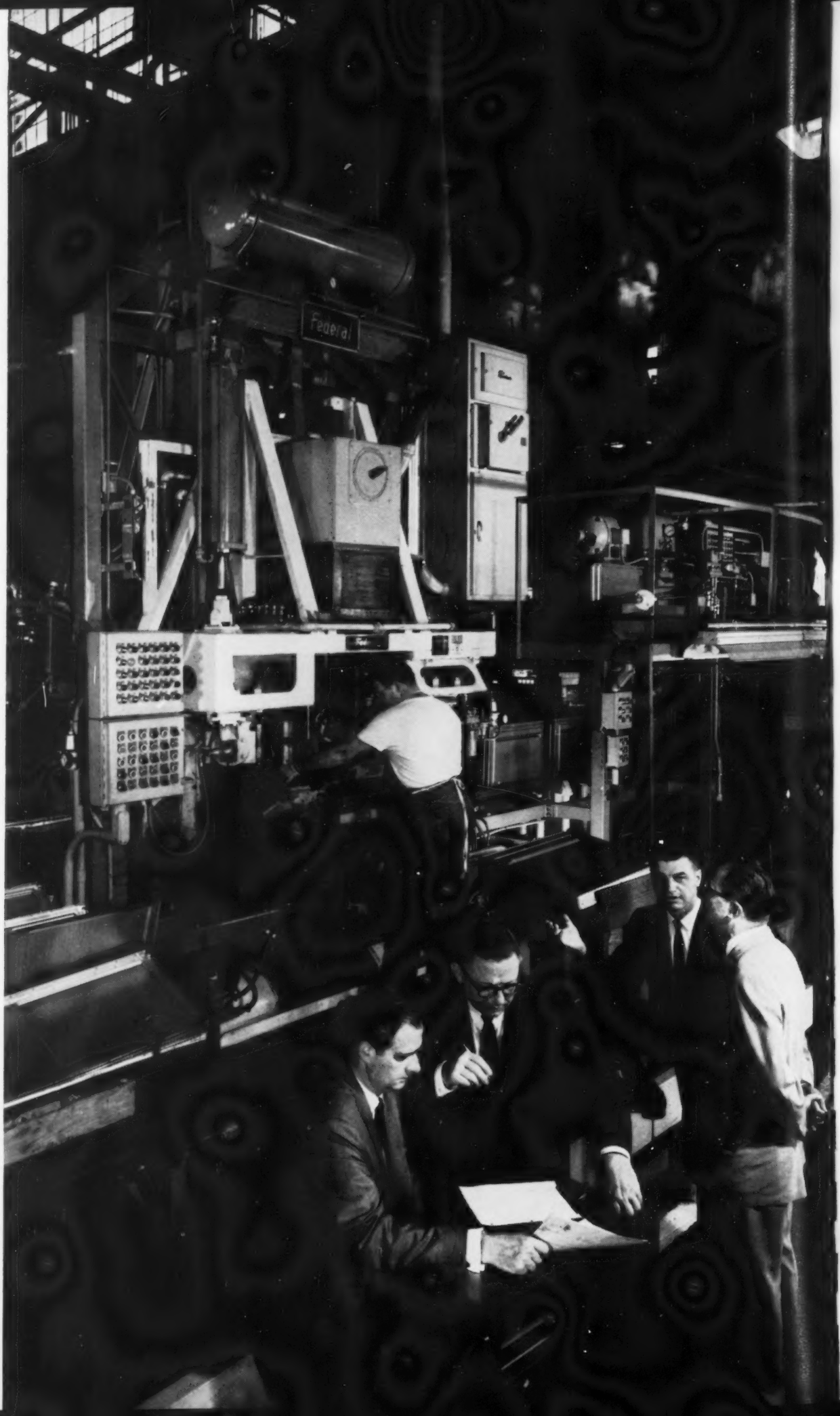
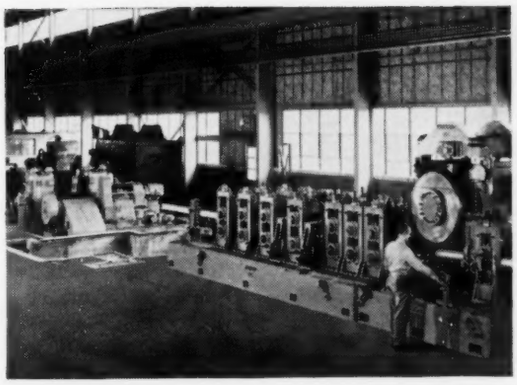


Federal Welding Line at Whirlpool's Evansville, Indiana, refrigerator plant automatically forms and welds together complete food liner shells at a rate of 200 per hour. Here, F. A. Bodenheim, Jr., manager of welder sales for McKay's Federal-Warco Division, goes over latest production charts with H. J. Muehlbauer, director of manufacturing engineering for Whirlpool, as Robert Bussell, sales representative for Federal-Warco, discusses operations with Gene Rommel, general superintendent of tooling for Whirlpool.

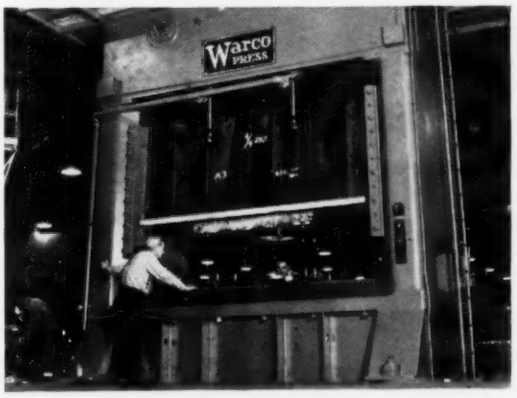
Photo by ARNOLD NEWMAN

A completely integrated plant . . . a single source of supply . . . one area of responsibility! A new idea? Not really, but an idea that's not easy to bring to reality. McKay Machine has done it for metal fabricators, designing and building equipment to volume produce parts or entire units from raw steel to finished product. ***This is McKay Machine*** We know steel handling . . . we've been designing uncoilers and coil-handling equipment for 30 years. McKay Machine knows welding because the highly respected names of Federal Welder and Berkeley-Davis are now a part of our company. We know processing and forming . . . McKay levelers, tube mills, and cold roll forming machines have been specified by leading industrial firms for more than two decades. And McKay Machine knows stamping, as the Warco Press name testifies. McKay builds the industry's most popular shearing and slitting equipment. Only McKay Machine designs and builds all the components for a truly integrated production line. If you are one of the hundreds of manufacturers who must shave production and handling costs to successfully compete, McKay Machine should interest you. If we do, let us know and we'll meet with you at your convenience. *The McKay Machine Company, Youngstown 1, Ohio.*

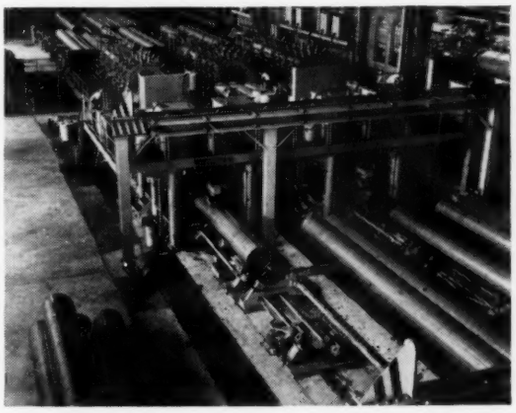
McKAY MACHINE



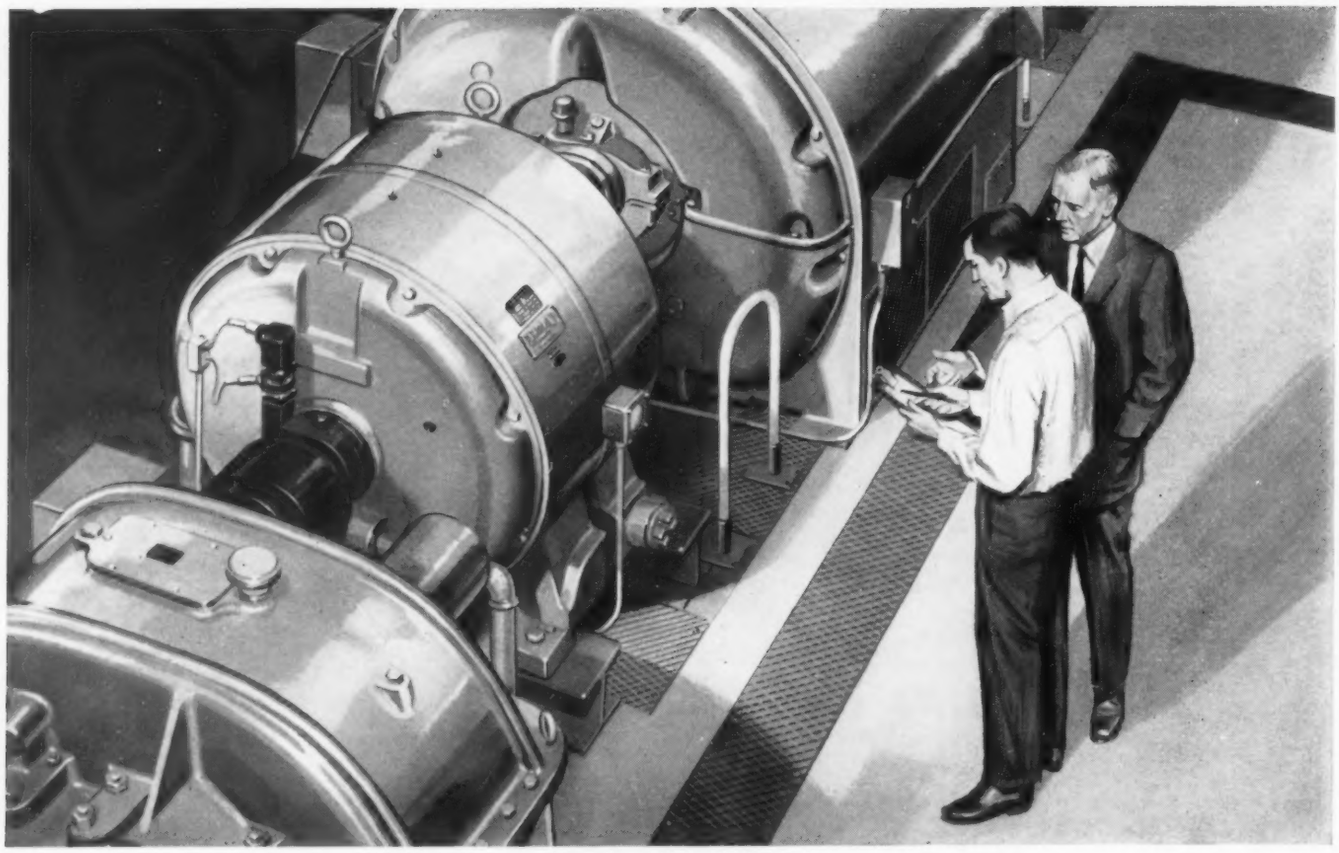
McKay Tube Mills and roll forming machines are considered among the best engineered in the world.



Warco Presses can be found in the leading automotive, appliance and aircraft plants . . . wherever stamping is a major operation.



Berkeley-Davis Fusion Welding Lines, such as the huge installation above, are used by an ever-increasing number of leading steel fabricators.



Place Your Speed Control Problems in the Hands of Experts!

As the originator and leading producer of eddy-current speed control equipment, it is only natural that Eaton-Dynamatic offers many exclusive design and construction advancements —plus expert engineering service.

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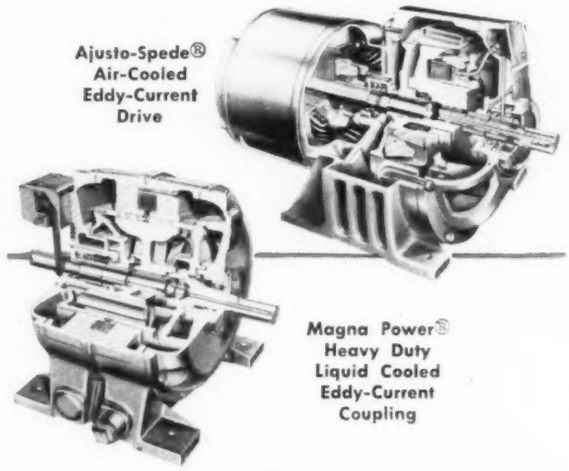
Representatives, located in all principal cities, are fully qualified to give you expert help with your speed control or torque transmission problems. Call the Eaton-Dynamatic representative nearest you today—there's no obligation.



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AUTOMATIC GAUGE CONTROL

OPERATING IN CANADA

56-inch 4-High Cold Reversing Mill at Dominion Foundries and Steel Limited, Hamilton, Ontario, which is equipped with the Davy-United system of Automatic Gauge Control. This mill rolls steel strip for tin plate between 24 inches and 50 inches wide in a range of thicknesses from .006 inches to .050 inches.

Six Automatic Gauge Control installations have now been completed or ordered in North America and Licensees in North America for the Davy-United system of Automatic Gauge Control include General Electric Company of the U.S.A., Canadian General Electric Company Limited and Canadian Westinghouse Limited.

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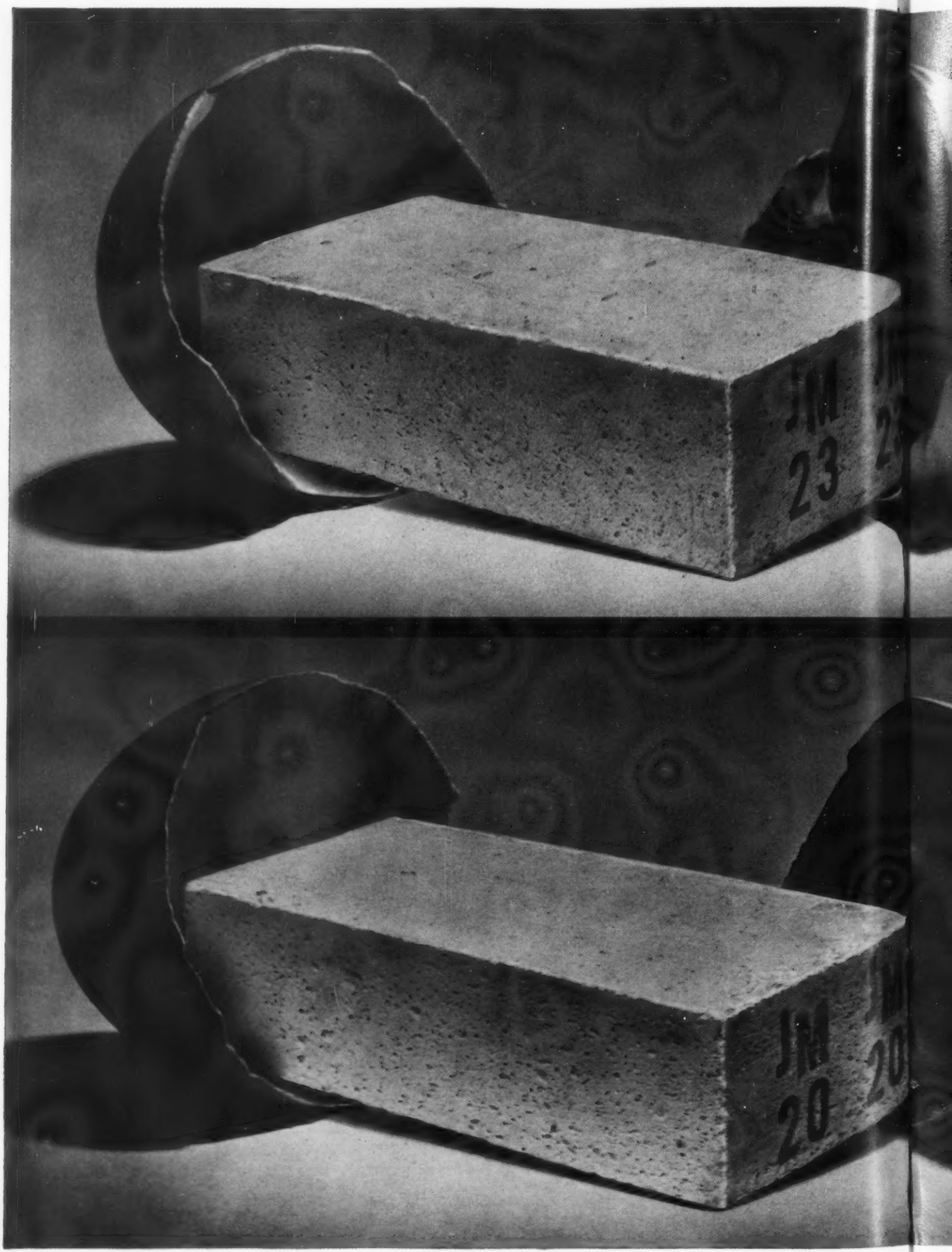
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New JM-23 and JM-20 Insulating Fire Brick Provide Outstanding Benefits

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- **LIGHT WEIGHT**—The new JM-23 weighs substantially less—about ⅓ less—than insulating fire brick previously available in its temperature range. The new JM-20 also is significantly lighter than the brick formerly available in the 2000F range.
- **HIGH STRENGTH**—Both brick have high cold crushing and hot-load strength.
- **HIGH INSULATING VALUE**—Both brick have an extremely low thermal conductivity.
- **SHAPES FROM SLABS READILY AVAILABLE**—Unique production methods perfected by J-M make it possible to cut accurate special shapes from slabs. The slabs are molded, fired rapidly through tunnel kilns and then cut into straights, arches, keys, wedges and a variety of other standard and special shapes.

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Crops and Shorts

△ Do big industry-wide unions create depressed areas? This is not a topic for a formal debate, but it is one that a lot of people are thinking about. Let's just consider an industry that is spread geographically over a wide area. Let's presume that this industry is faced with a big union which sets up a uniform pay scale for all plants. Let's further presume that some of the plant locations are handicapped by raw material costs higher than those of other areas. Perhaps some plants, because of age or size, are not as efficient as others. Into this picture might come a period when only 60 to 70 per cent of this industry's capacity is needed to meet customer's requirements. Then, do all plants run at 60 or 70 per cent capacity? Or do the low-cost plants operate at 90 or 100 per cent while the high-cost plants are idle? If it should be the latter case, would a lower wage scale for the otherwise handicapped plants permit them to open up and provide jobs in their areas? Perhaps living costs in their areas might even be lower than in other areas, so the lower wages might bring just as much of this world's comforts. Would a big union permit this? As we asked before: "Do big industry-wide unions create depressed areas?"

△ Research & Review Service's house magazine says: "If you want your father to take care of you, that is paternalism. If you want your mother to take care of you, that's maternalism. If you want the Federal Government to take care of you, that's socialism. But if you want to take care of yourself, that's Americanism."

△ Lightweight tin plate continues to occupy the limelight. Thus far, it has been made principally on equipment originally put in for regular tin plate. Weirton expects to complete the first installation specially designed and constructed for the light plate. Jones and Laughlin is said to be planning similar facilities.

△ Listening to speeches made by government officials of various levels reminds us of old Speaker Joe Cannon's reaction to a speech: "Much of what you said was good and some was new. But what was good was not new and what was new was not good."

△ More competition is in sight for mill machinery builders trying for export business. An agreement has been signed between Demag of Western Germany and Hitachi Shipbuilding and Engineering Co. and Kinoshita Sansho, of Japan, to form a new company, Nichi-Doku Jukogyo Yugan Kaisha.

△ R. Conrad Cooper, U. S. Steel Corporation executive vice president—personnel services, told a University of Michigan audience that increased production costs, particularly employment costs, have severely weakened the nation's steel industry's position in world trade. He pointed out that since 1950 the United States' percentage of world steel ingot production declined from 47 per cent to 27 per cent. Exports declined from 15 per cent of world steel trade to only 7 per cent while imports into the United States increased from $1\frac{1}{2}$ per cent of domestic supply to almost 5 per cent.

△ A new steel plant, Sidemar, is to be built near Ghent, Belgium, by Belgian and French interests. Initial output is to be 1,500,000 tons per year, rising eventually, to 2,500,000 tons.

△ One of our old-fashioned friends bemoans the fact that modern homes have a switch for everything but the children.

△ According to the National Fire Protection Association, the United States had 2,000,000 fires in 1960. They took the lives of 11,350 people and caused monetary loss of $1,541,000,000.

△ With a first half production of 44,857,804 tons and third quarter prospects for 25,000,000 tons, the steel industry is going to need a finishing line spurt to hit the 100,000,000 tons predicted for 1961.

△ Various British steel works are now installing one rotor plant, three Kaldo plants and five L-D (or L-D/AC) plants.

△ Between 1947 and 1960, the gross national product more than doubled, but profits before taxes increased about 50 per cent and profits after taxes little more than 25 per cent.

△ Have you seen any of the "I miss Ike" stickers which appear on some automobiles? Probably Republicans.

△ William A. Steele, chairman and president of Wheeling Steel Corporation, believes that third-quarter steel operations depend on the automobile and canning industries. He anticipates continued improvement in the final quarter of 1961, but warns profit margins will be affected by the October wage increase.

△ Kreolite News observes: "Three meals a day, roof over my head, two cars, a boat, a power mower and a contented wife—why shouldn't I be in debt?"

D. I. S. STRIPS 10-INCH SCALE FROM 12-INCH PIPELINE IN JUST ONE DAY!

Dense scale deposits of oxides, sulfides and sulphur—10 inches thick in some places—clogged a 12-inch fuel supply line. Dow Industrial Service engineers stripped every trace of deposits from this 750-foot pipeline—restoring full capacity—in *just 24 hours!*

Solvents and a pipeline pig did the job. But for different conditions, D. I. S. uses other techniques to get the same result. For example, when scale blocked a 24-inch, quarter-mile-long waste line, D. I. S. engineers knocked out the deposits with a special D. I. S.-designed jet mole. Though this underground pipeline was buried 10 feet deep, D. I. S. cleaned it completely in only 16 hours!

Nation-wide Dow Industrial Service first analyzes the job to be done, then selects the technique which will do the best job, fastest. D.I.S. cleans all kinds of lines—fresh water, boiler feed-water, gas, waste and other lines—and every kind of process and heat exchange equipment.

In addition, D. I. S. offers complete consulting laboratory service for water treatment and waste processing problems, backed by the technical resources of The Dow Chemical Company. For cleaning *any kind* of equipment, *anywhere* in the U. S., write or call DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, Ohio.

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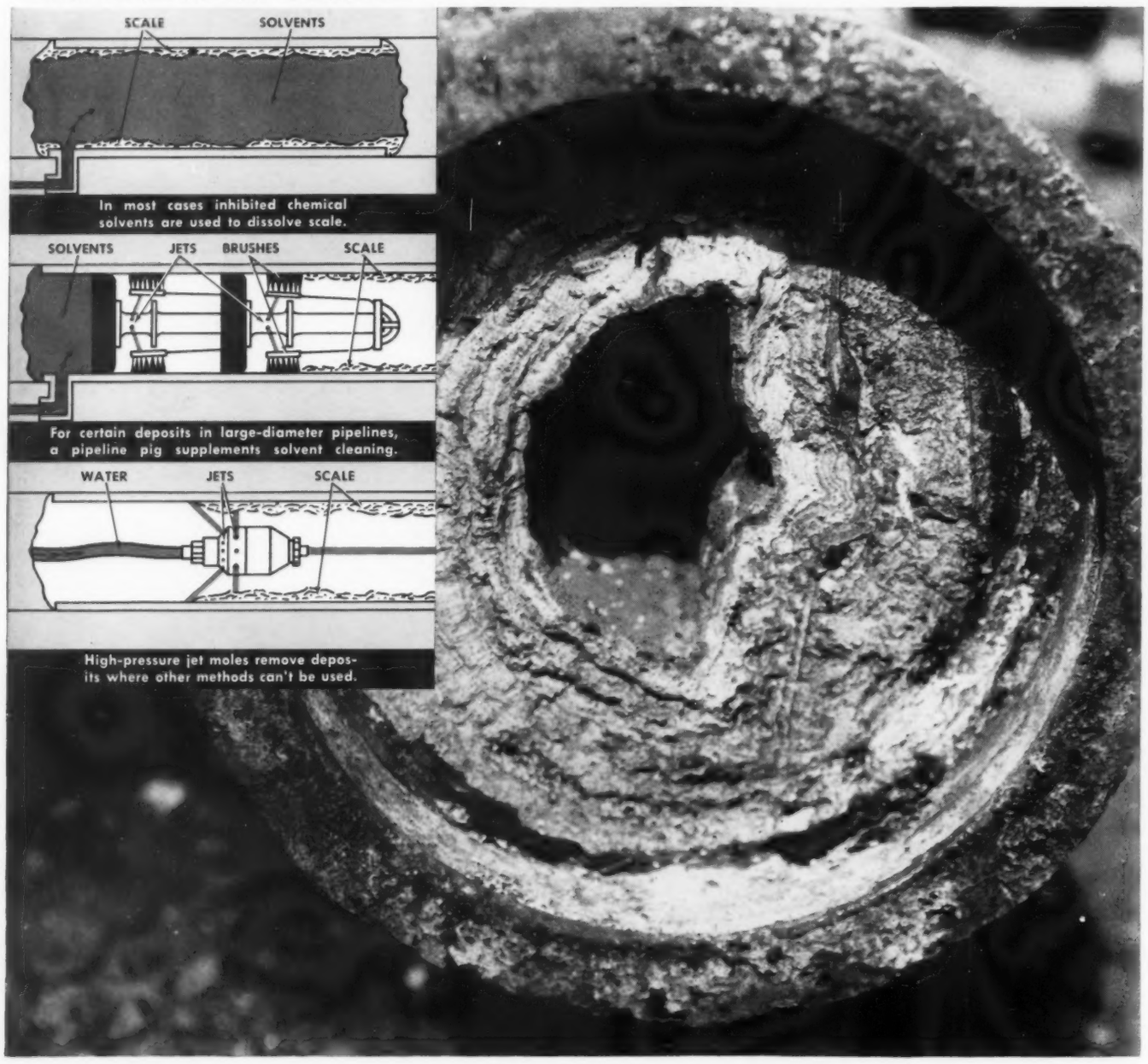
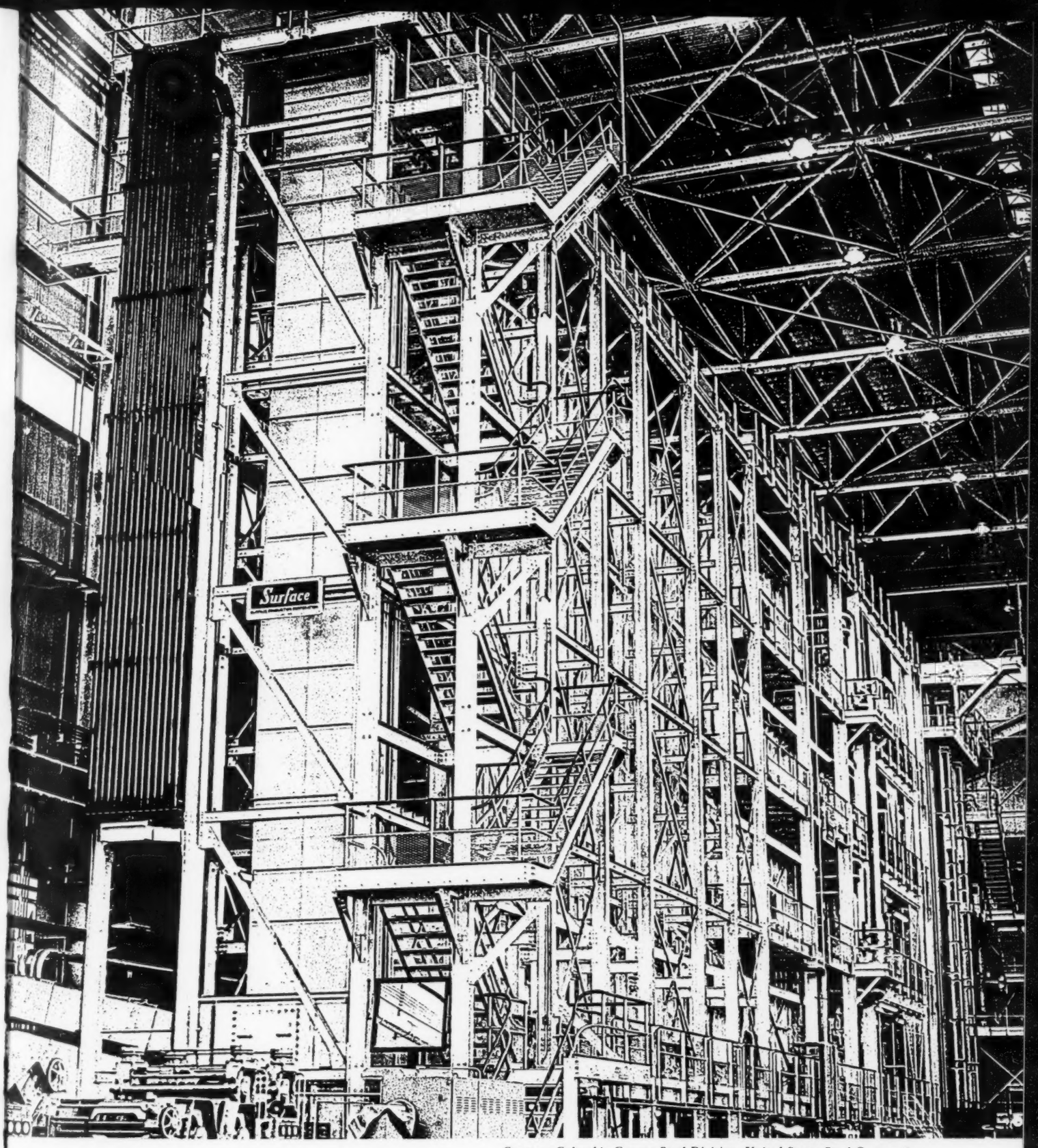
From these three methods, D. I. S. selects the one best suited to your specific pipe-cleaning problem.

In most cases inhibited chemical solvents are used to dissolve scale.

For certain deposits in large-diameter pipelines, a pipeline pig supplements solvent cleaning.

High-pressure jet moles remove deposits where other methods can't be used.





Courtesy Columbia-Geneva Steel Division, United States Steel Corporation

Sign of performance better than specified: The modern tin plate industry demands highest quality at lowest operating cost—requirements which can be met only with continuous annealing, a process pioneered by Surface. This Surface installation produces 96,000 lbs/hr of .010″ strip at speeds up to 1500 fpm. Address inquiries to 2404 Dorr Street, Toledo, Ohio.

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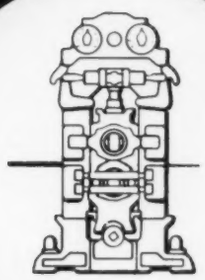
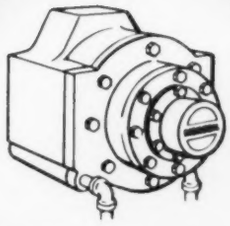


ROLLING MILLS



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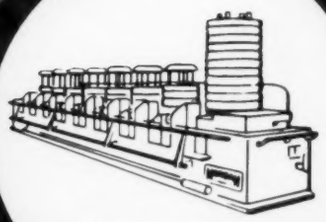

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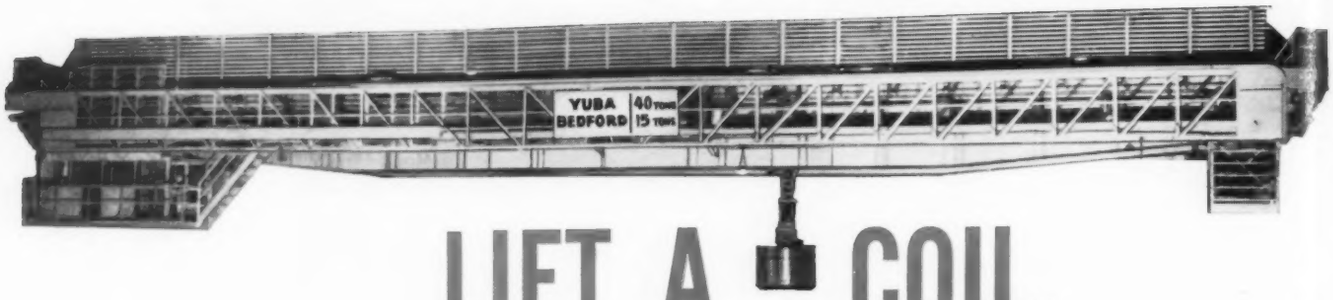

LIFT A COIL, SCRAP, OR LADLE

40/15 ton, 120 ft. span Yuba Bedford Crane in sheet mill coil storage area at U.S. Steel's Gary Sheet and Tin Mill, Gary, Indiana.

. . . JOBS FOR YUBA BEDFORD CRANES

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SINTERING—to achieve maximum quantity and quality of output at lowest cost.

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S121-1

IRON AND STEEL DIVISION

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Down go back-up roll costs with (U S

ith (U S) Quality Forged Sleeves

Pictured above is James S. Rennick, a metallurgist with twenty years' experience in the Forgings Division of U. S. Steel. Jim specifies composition, heat treatment, and other processing procedures essential to the production of assemblies as shown in the main picture—a back-up roll that will be used in the cold reduction tin mill at U. S. Steel's Gary, Indiana, plant.

This job points up a curious situation: U. S. Steel is one of the country's leading manufacturers of rolls, and also one of the biggest *users* of rolls . . . a double reason to perfect their performance and reduce their cost . . . just as we did here.

We had to replace a worn, cast steel back-up roll. Rather than replace the entire roll, we machined the face of the roll and shrunk on a *forged* steel sleeve. For back-up rolls like this one, 42" O.D. and larger, this method of sleeving is much less expensive than buying a complete new roll. One arbor can be used for several forged sleeves. A forged sleeve has a hard, wear-resistant surface and is highly resistant to spalling.

Also, the sleeve is purposely produced with a softer bore to develop a desirable stress pattern, and to provide maximum gripping between the arbor and sleeve after assembly.

There is a good possibility that we can help reduce *your* roll costs. Write or call the United States Steel Office nearest you, or United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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WAGNER® HYDRAULIC CRANE BRAKES *help speed cargo handling*

There are four Wagner® Hydraulic Crane Bridge Brakes aboard Inland Steel Company's S. S. EDWARD L. RYERSON. Specially engineered for high holding torque, they are used for parking and holding the gantry crane that handles the ship's hatch covers. These four Type HM 6″ x 3″ brakes are all operated from one station . . . make it possible to open hatches with the speed and safety that results in faster handling of cargo.

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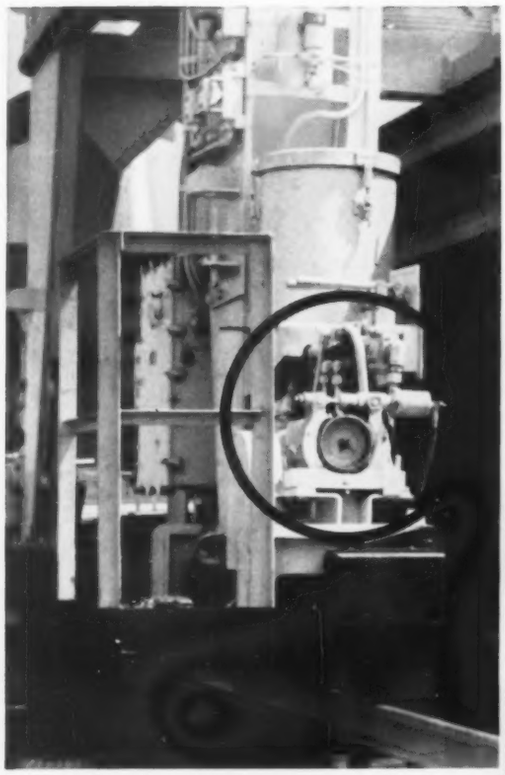
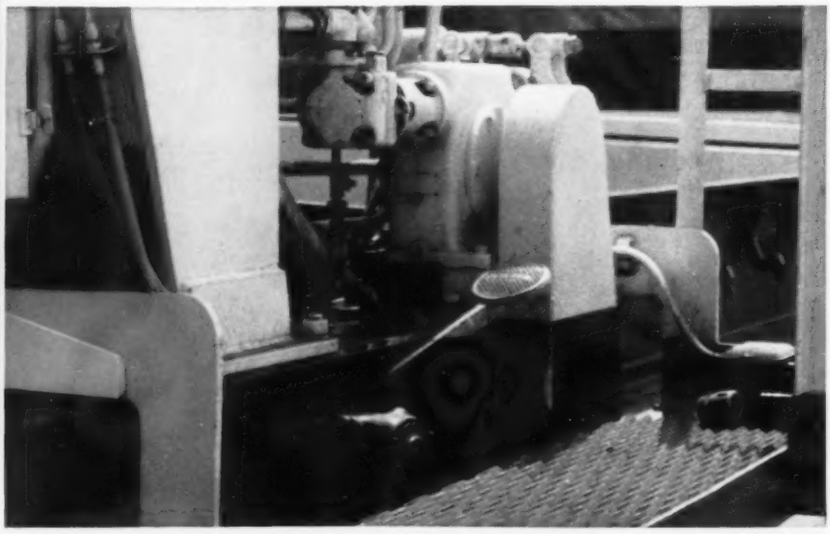
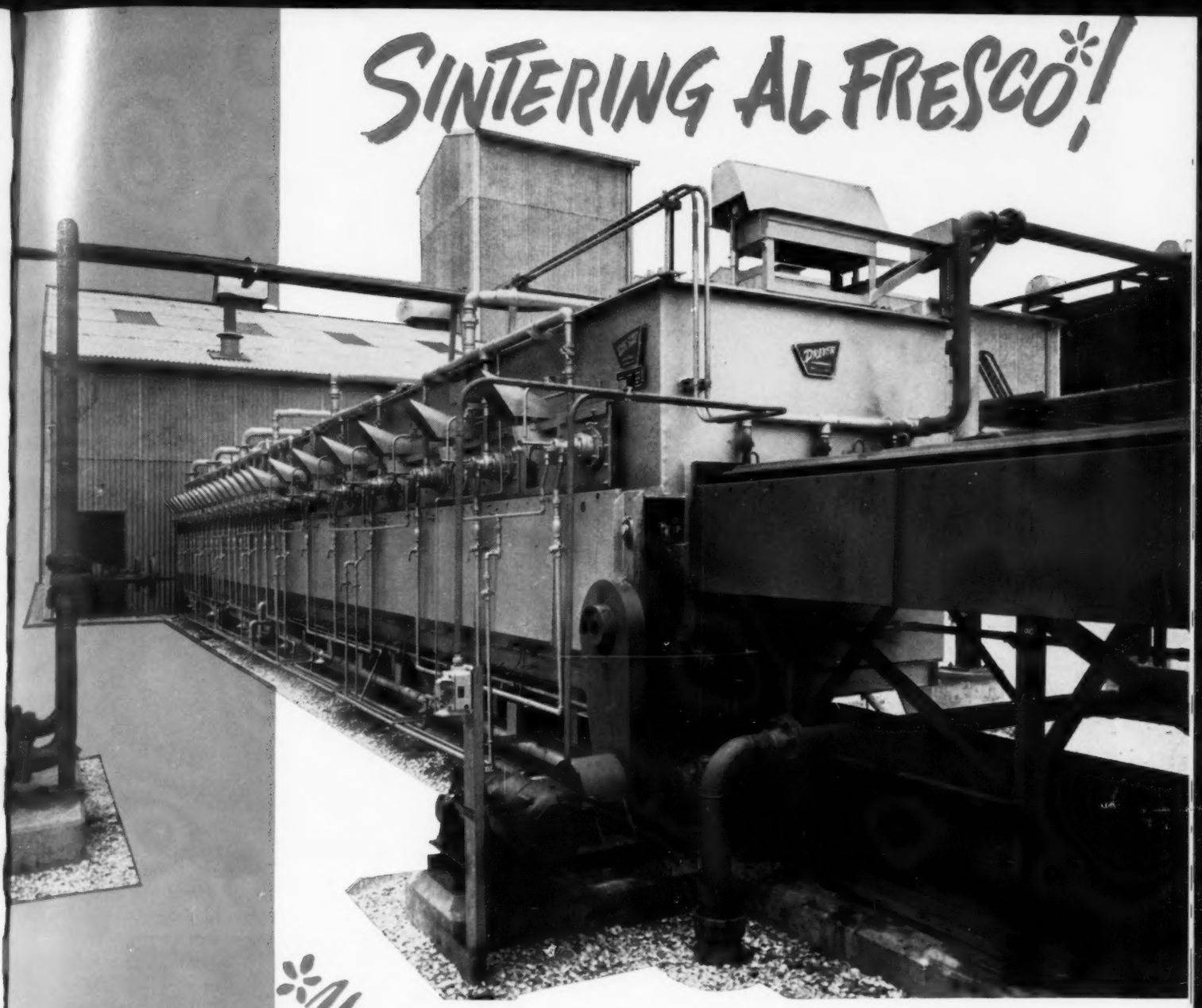


One of the four Wagner type HM hydraulically operated service brakes, with spring-applied parking means, that help speed the opening and closing of the hatches to minimize "hold-up" of the ore boat at the dock.



All four Wagner brakes on the S. S. EDWARD L. RYERSON'S gantry crane are operated from this single station.

SINTERING AL FRESCO!



YES, OUT-OF-DOORS! Here's a Drever Furnace installation for sintering nickel briquettes at the plant of the Freeport Nickel Company, Port Nickel, Louisiana. Its outdoor setup eliminates the need for costly building space—but this is only one of its interesting features.

HIGH LOAD CAPACITY—AUTOMATED OPERATION

Built to handle continuous in-line 8800# per hour production of sintered nickel briquettes, this Drever Furnace combines the high loading capacity of a roller hearth with the material handling convenience of a conveyor belt furnace. It is a radiant-tube, natural gas fired, roller hearth type furnace, gas tight for controlled atmosphere operation.

NO TRAY LOADING OR UNLOADING

Material passes through the furnace on a continuous mesh belt which allows greater circulation of heat and gas for uniform production and eliminates the need for trays. Automatic handling equipment loads briquettes onto the belt and conveys the sintered briquettes from the end of the furnace for weighing and packaging.

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This unique out-of-doors installation is an example of Drever application of sound engineering principles, and experience in the field of furnace design. Our engineering staff is available for consultation concerning your requirement—write or phone us. Drever Company, Bethayres, Pa. Phone: WIlson 7-3400.

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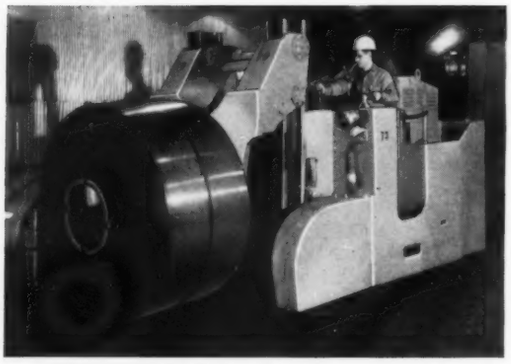

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TWICE THE LIFE...ONE THIRD THE OPERATING COST

patent reviews

By MELVIN NORD, Patent Attorney, Detroit, Mich.

Copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents . . . patents reviewed cover period March 28, 1961 to April 18, 1961.

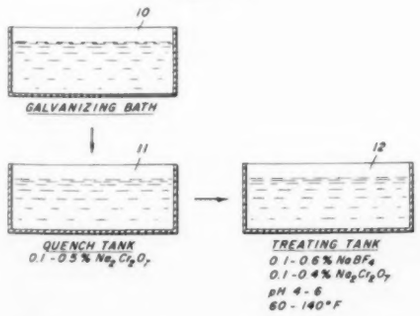
INHIBITING WHITE RUST ON ZINC SURFACES

△ U. S. Patent 2,977,259, issued March 28, 1961 to Ludwig E. Schmelzer and assigned to United States Steel Corp., provides a method for inhibiting the formation of white rust on zinc-surfaced articles such as galvanized iron.

As shown in Figure 1, pipe lengths are delivered successively from a hot-dip galvanizing bath 10. The lengths are transferred immediately to quench tank 11 containing a very dilute water solution of a dichromate such as sodium, potassium or ammonium dichromate. This solution contains only from 0.1 to 0.5 per cent of the salt by weight. The heat absorbed by the solution in cooling the lengths may raise the solution temperature nearly to the boiling point in continuous operation. After from one to four min, in tank 11, the lengths are removed and placed in a treating tank 12.

Tank 12 contains a water solution of hydrofluoboric acid or a salt thereof and a dichromate.

Figure 1



Its acidity is adjusted to a pH of from four to six. The fluoborate may be the sodium or potassium salt. The concentration is from 0.1 to 0.6 per cent by weight. The concentration of dichromate is from 0.1 to 0.4 per cent by weight. This mixed solution clears up the coloration imparted by the quench in a time interval permissible in line production, and leaves the product with its freshly galvanized appearance. The temperature of the solution is controlled between 60 and 140 F. A higher temperature of the solution in tank 12 will cause some of the yellow coloring to remain on the product. Immersion time in tank 12 is kept to within two min. A time shorter than one min fails to effect removal of the yellow coloration. On removal of the lengths from tank 12, for the desired finishing operations and storage, they will be found uncolored and characterized by a high resistance to the formation of white rust.

The stated range of pH for the treating solution is important. If it exceeds six, a pale yellow cast may be left on the product. If it is below four, the etching action of the fluoborate is objectionable. The pH is adjusted initially with sodium hydroxide whether the salt, sodium fluoborate, is added as such to water or fluoboric acid is used in conjunction with sodium hydroxide to form sodium fluoborate in water solution. If the pH should inadvertently go above five by excess addition of sodium hydroxide, fluoboric acid is added to reduce the pH to the desired value. The dichromate is added after the desired pH has been attained. A concentration of fluoborate exceeding the stated range leads to a salt formation on the surface of the pipe.

PRODUCTION OF STEEL INGOTS

△ U. S. Patent 2,976,586, issued March 28, 1961 to John O. Briggs, describes apparatus for the continuous casting of steel ingots and their transportation into a blooming mill, without requiring soaking pits.

As shown in Figures 2, 3 and 4, the ingot molds 21 are placed in position where they are engaged by the heads 33 and 34 with the mold sections being supported upon the rolls 20 on each side of the roller bed and the mold sections manipulated to a closed position, in which position the ladle 39 is brought into position so the discharge opening 41 is spotted over the mold above the intake openings 27 and 28 whereupon the operator, by manipulating the lever 48, raises the plug 44 out of the opening 41 and permits the molten steel to flow from the ladle into the openings 27 and 28 to fill the cavities 24 in the mold 21 to a point where the mold is completely filled with molten steel when the flow from the ladle is shut off. The molten steel entering the mold cools very rapidly and becomes sufficiently hard to retain its shape and once this occurs, the members 37 are actuated reversely to the

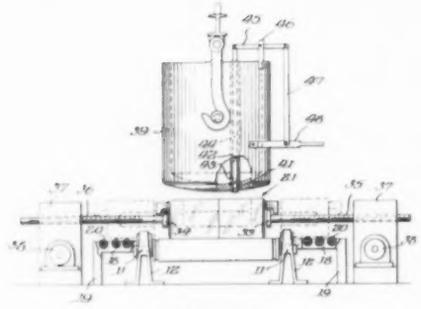


Figure 2

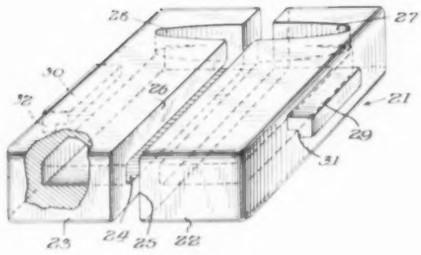


Figure 3

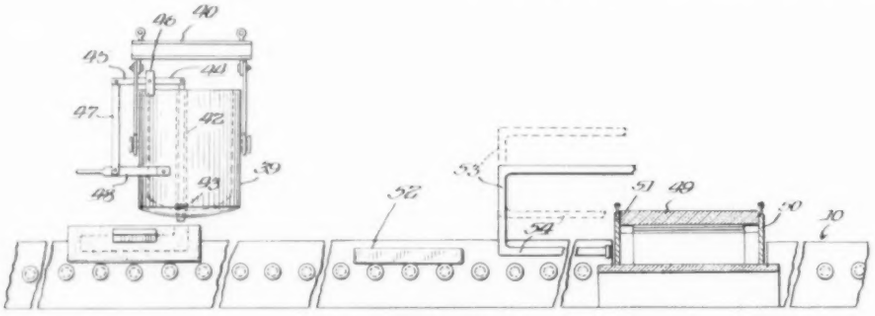


Figure 4

closing operation which pulls the mold sections 22 and 23 apart, permitting the ingot 52 to drop onto the rolls where it is moved through the reheating furnace and transported either by manual movement or by the pusher 53, or by the combined use of the pusher 53 and the motor mounted rolls directly into the blooming mill which commences the rolling operation and which can be thereupon completed to the desired shape and form of the structure desired.

CASTING STEEL INGOTS

△ U. S. Patent 2,976,587, issued March 28, 1961 to Henri J. Daussan, provides a method of casting effervescent and killed steels.

As shown in Figure 5, the pouring jet J is enveloped in a sheet metal tube 13 fitted with an upper asbestos sleeve 14, resting in a disk 43 consisting of fireproofed corrugated cardboard wound as a spiral to act as a dampener of the impact of the jet.

Before casting is started, each of the chambers a, b, c and d of the apparatus is evacuated, and desired pressures may be maintained during the casting by continuing to evacuate the gases liberated. The tube 13 progressively melts as the surface of the molten bath rises. By varying the pressures prevailing at a and d, it is possible to vary materially the level of the metal situated in the end of the tube and thus considerably increase the effectiveness of the degassing, puddling or stirring.

In the case of effervescent steel, it is possible with this method, to conduct the degasification in such manner that the peripheral pure iron zone of the ingot is thick and such that hydrogen is free to escape. This same advantage is obtained in killed steels, as concerns elimination of the hydrogen and thus avoids, in the cooled ingot or in the products composed thereof, dangerous internal stresses and the formation of cracks or flakes.

In the case of alloyed killed steels, it is possible to avoid to a great extent the formation of oxides.

The gases extracted from the molten metal and conducted toward the center of the molten metal bath play a useful role in the elimination of impurities (solid inclusions) up to the upper and central part of the bath.

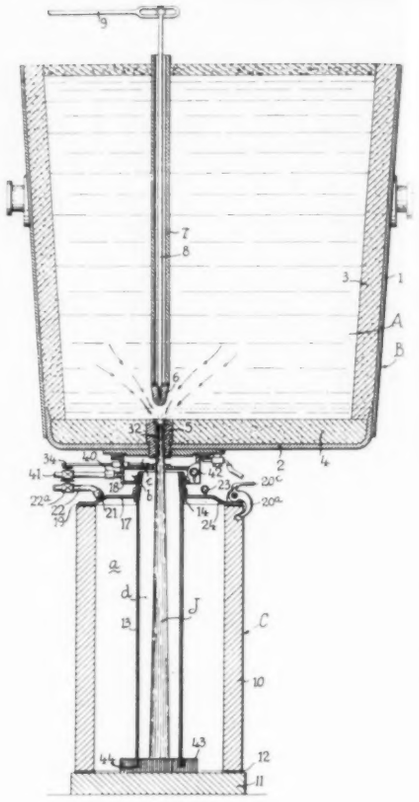


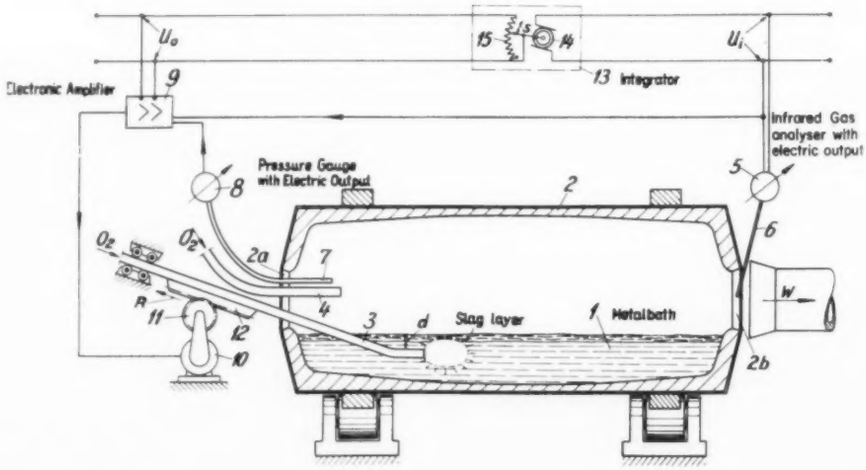
Figure 5

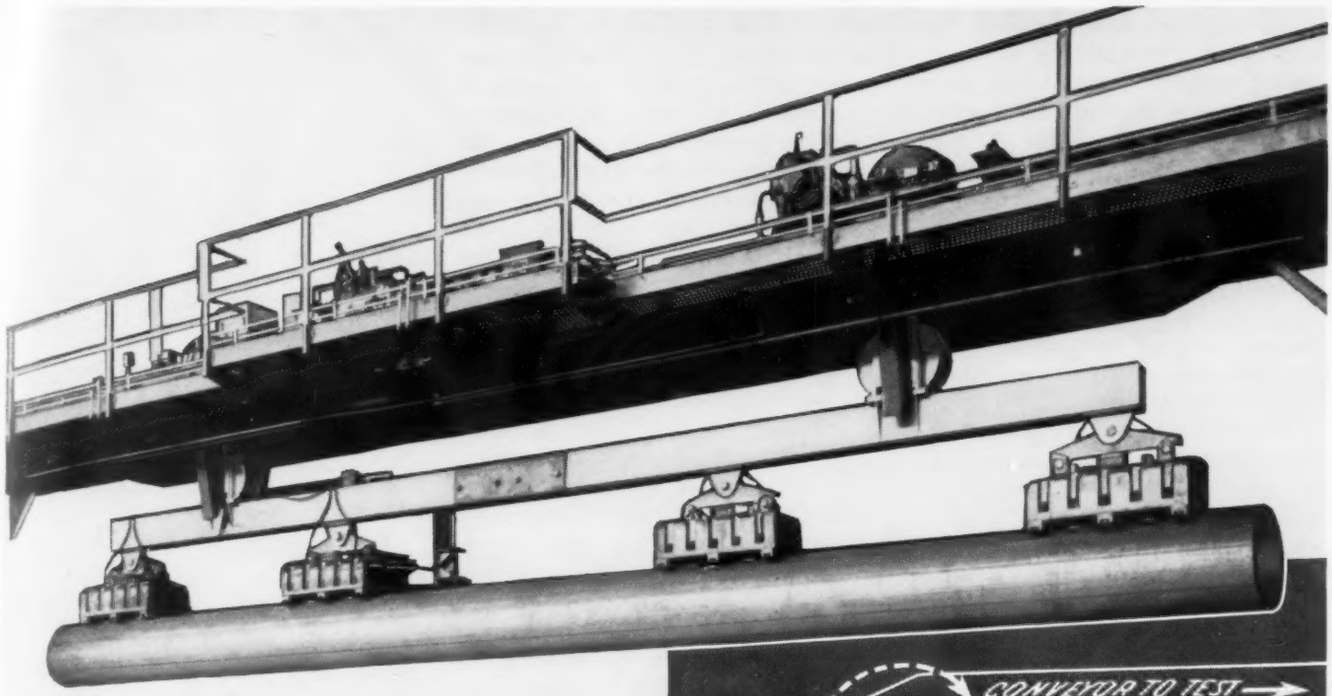
ROTARY DRUM REFINING FURNACES

△ U. S. Patent 2,977,217, issued March 28, 1961 to Rudolf F. Graef and Ludwig A. von Bogandy, assigned to Huttenwerk Oberhausen A. G., relates to rotary drum furnaces for refining steel.

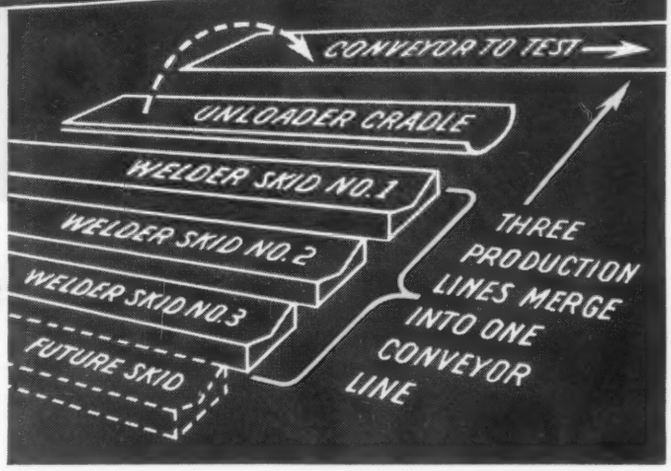
As shown in Figure 6, the metal bath 1 is contained in a drum 2 lined with ceramic material and is refined by a blast of oxygen. The

Figure 6





4 EC&M pipe magnets lift a 40-foot length of 30-inch diameter pipe from seam welding line to test conveyor



EC&M-equipped Crane

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Pipe initiates the movement of this new automatic crane at Bethlehem Steel Company's Line Pipe Mill in Steelton, Pa. The crane operates only when necessary, then returns to the home position over the unloader cradle — remains there until new pipe commands further movement.

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oxygen is supplied beneath the surface of the bath by a water-cooled primary nozzle 3 and above the surface of the bath by a water-cooled secondary nozzle 4, both nozzles extending through the same opening 2a in the end wall of the drum.

An analyzer 5 continually determines by means of a probe tube 6 the composition of the waste gases leaving through opening 2b in the opposite end wall of the drum as indicated by arrow W.

Above the secondary nozzle 4, a water-cooled tube 7 which acts as a pressure probe, passes through opening 2a into the interior of drum 2 above the metal bath. To this tube is connected a pressure meter 8 which measures the pressure in the drum practically instantaneously and continuously. In this instrument, deviation of the pressure from a set datum value is converted into a weak electrical impulse which is amplified in an amplifier 9. The amplifier 9 actuates an electrical motor 10 in its output circuit controlling by means of a gearing 11 and a rack 12 the depth of immersion d of the primary nozzle 3. Whenever the pressure read by the instrument 8 exceeds the set datum value, a positive difference voltage of a magnitude proportional to the pressure deviation is fed to the amplifier 9 amplified by the latter and passed on to the motor 10 which then withdraws the nozzle in the direction of arrow R, thereby decreasing immersion depth d. When the aforesaid pressure is too low, the reverse takes place. If the nozzle is controlled in accordance with any preset datum pressure, a constant CO content is obtained in the waste gases but that CO content is not necessarily the desired content. To ensure that the desired CO content in the waste gases is the one maintained by the above arrangement, the difference between the desired and the actual CO content measured by the analyzer 5 is also applied as a difference voltage to the amplifier 9. Thus, if, for example, the CO content of the waste gases is constant but too high, the amplifier 9 receives from the analyzer 5 an additional voltage of a sign opposite to that of the voltage from the pressure measuring instrument 8. This additional correcting voltage produces the same effect as would a correction of the datum pressure in the sense necessary to make it correspond to the desired CO content. The pressure no longer oscillates about the datum pressure to which pressure meter 8 is set, but about a pressure which lies above or below the datum pressure depending on whether the CO content of the waste gases is above or below the desired value. The CO content thus adjusts itself gradually to the desired value and as soon as the latter is reached, the correcting impulse from the analyzer 5 will disappear. However, disappearance of the corrective impulse renders operative the original datum pressure which, as previously mentioned, does no longer correspond to the correct, desired CO content. To prevent this, there is provided between the analyzer 5 and the amplifier 9 an integrating device 13, which stores and supplies to the amplifier the deviation in CO content from the desired value. This storage can readily be effected by causing the impulse to control the speed of rotation of a Ferraris motor 14 which adjusts a voltage selector 15 in the sense required to make the output (secondary) voltage proportional to the primary voltage multiplied by the time for which this primary voltage has prevailed.

DESULPHURIZING PIG IRON

△ U. S. Patent 2,979,393, issued April 11, 1961 to Russell P. Heuer, Jr., provides a process for desulphurizing pig iron.

As shown in Figure 7, molten pig iron 23 is introduced into a mixer type ladle 20, having a tight refractory lined cover 21, and a refractory lining 22. The lance 24 extends into the vessel through the cover and is supplied with a stream of nitrogen at 25 in which is suspended the desulphurizing agent 26 by an injector 27 supplied with nitrogen at 28. A cover escape vent 30 carries off the excess gas. There are pouring openings at 31 available to discharge the molten pig iron.

The desulphurizing agent is ground so that 90 per cent of it passes through a tyler standard 40 mesh per linear in. screen. The quantity of desulphurizing agent is between 1 and 50 lb per ton of molten pig iron. The gas stream impinges

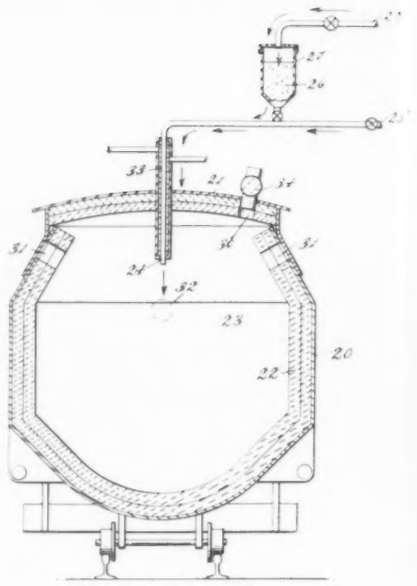


Figure 7

upon the surface 32 of molten iron. The lance is also provided with a water jacket of 33. The lance is preferably made of a heat resisting metallic alloy or refractory material. The pressure is maintained in the vessel by adjusting the inflow of gas through the lance, as compared to the outflow through exit vent 30 controlled by partially opened valve 34. This prevents substantial infiltration of air or other oxidizing gas into the vessel.

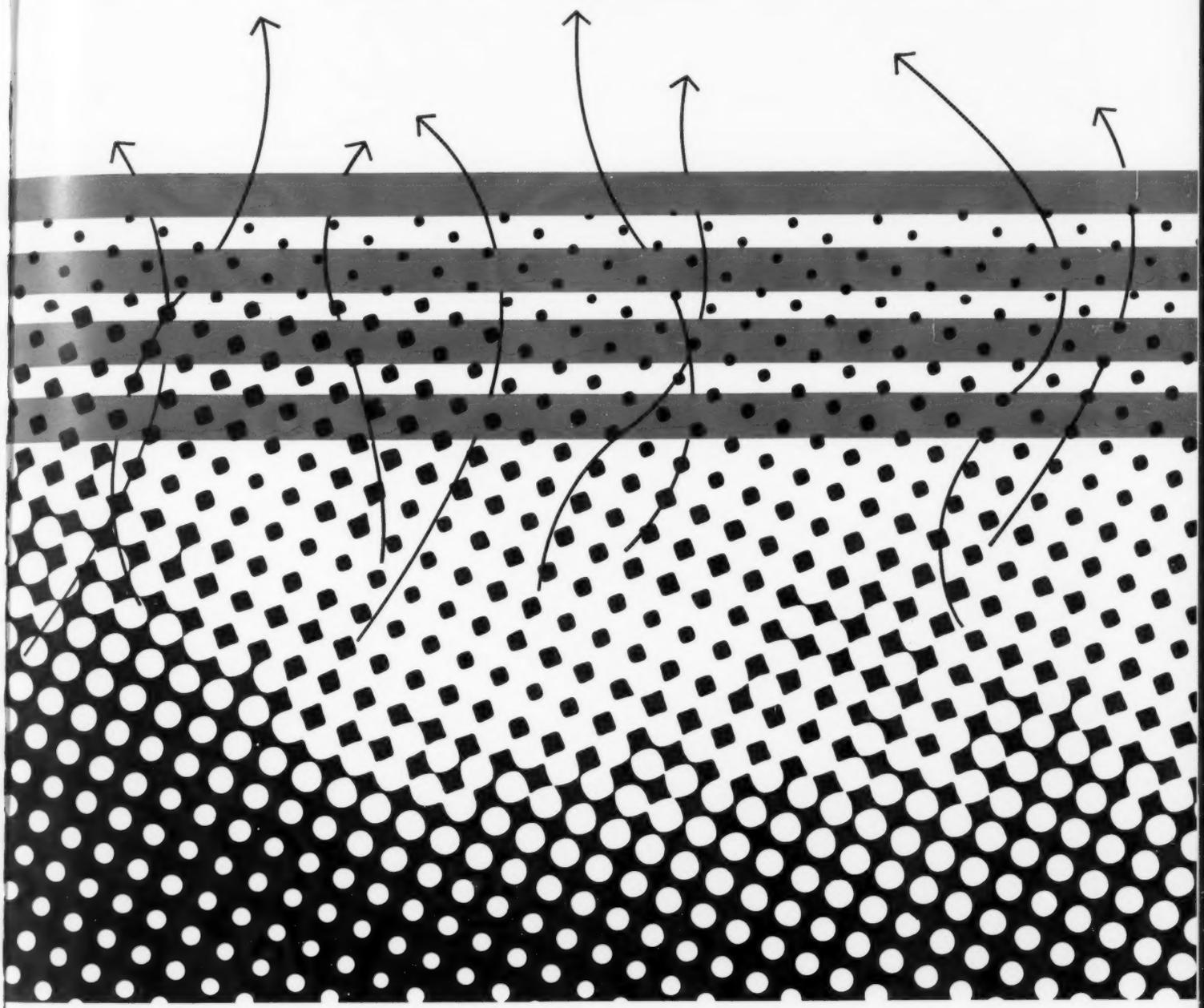
The treatment is continued until the desired amount of gas and the desulphurizing agent has been brought into operation. The sulphur content of the molten pig iron can be reduced until it is 50 per cent by weight of the original sulphur content, or 25, 10, 5 per cent or less. Final sulphur content may be as low as 0.001 per cent sulphur by weight.

After the treatment the flow of the stream of gas and powdered desulphurizing agent is terminated, the lance is removed, and the iron is removed from the vessel for refining into steel or other uses as required. The supernatant desulphurizing powder may be removed before or after the iron is removed.

DECARBURIZATION AND DEPHOSPHORIZATION OF PIG IRON

△ U. S. Patent 2,979,395, issued April 11, 1961 to Johannes Kosmider and Herbert Neuhaus, provides a method of removing carbon and phosphorus simultaneously from

AIR POLLUTION CONTROL



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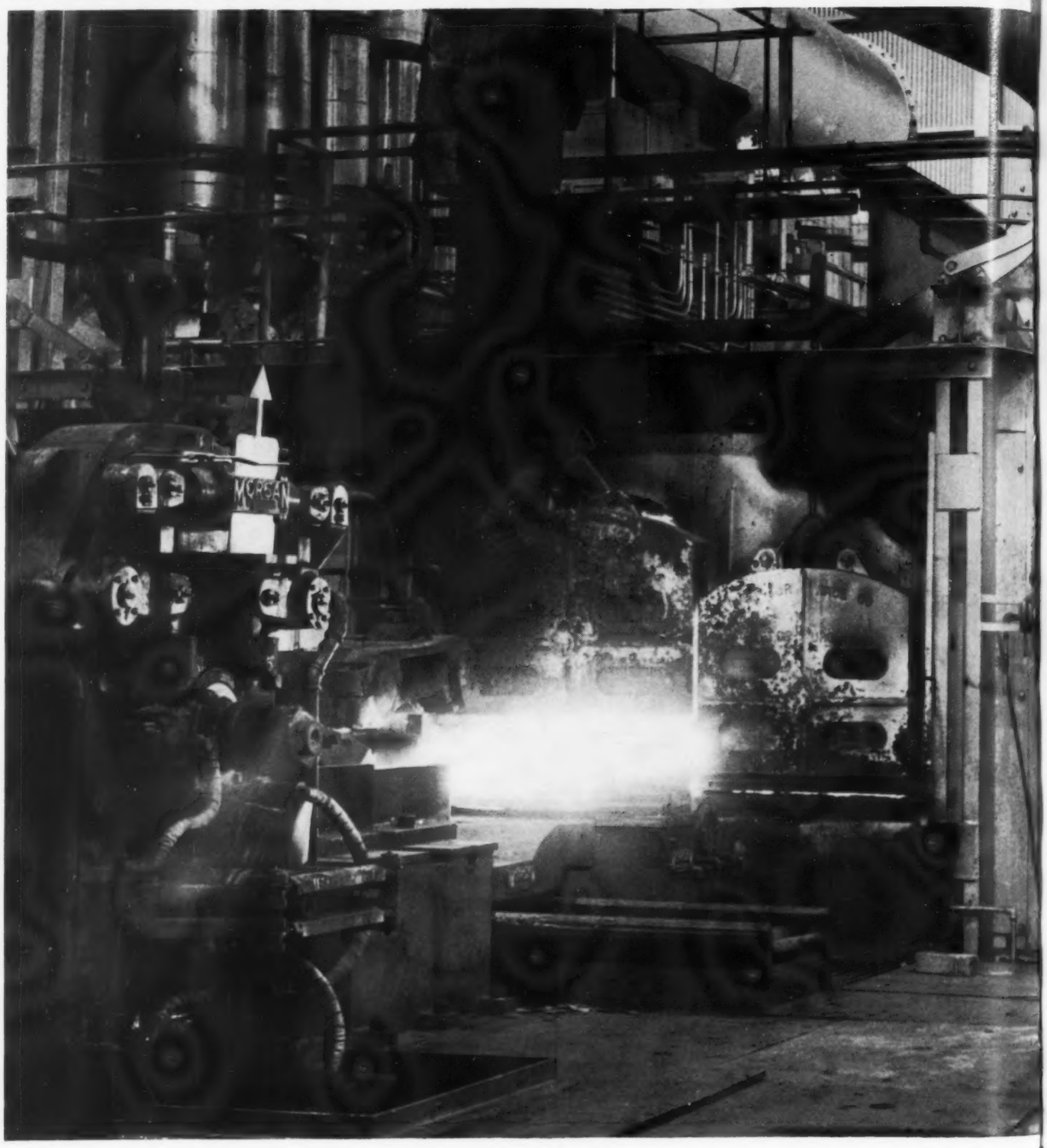

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HAGAN POWRMAG

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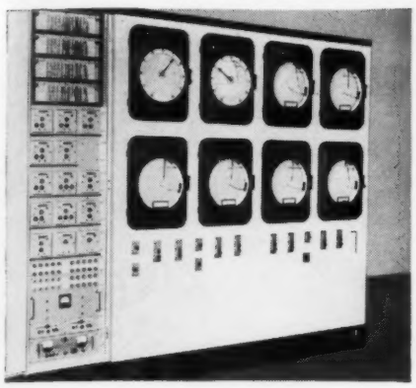


FIRST IN THE STEEL INDUSTRY AT BETHLEHEM'S STEELTON WORKS

A two-zone Rust billet-heating furnace at Bethlehem's Steelton Plant is equipped with Hagan PowrMag® (magnetic amplifier) electronic controls. Hagan systems on this new furnace include zone temperature, fuel/air ratio, furnace pressure, air pressure, and recuperator temperature balance control.

Using Hagan PowrLog® recorders and PowrMag controllers, the system provides for parallel operation of combustion air dampers and fuel oil control valves in each zone. An unusual feature of the furnace is the two stack-type recuperators. These must have waste gas flow regulated so that temperatures are equal in each recuperator, and this must be accomplished by the same dampers that regulate furnace pressure. The control system accomplishes this by using furnace pressure as the primary control impulse, moving both stack dampers in parallel. Temperatures in both stacks are continuously sensed, and a controller moves one of the dampers to maintain the two temperatures at the same level.

This installation is a part of the move towards more centralized control that has interested the steel industry for some time. A Hagan engineer will be glad to discuss how this principle can be applied to your plant. Or, ask for Bulletin MSP-163. Write or phone:

HAGAN

CHEMICALS & CONTROLS, INC.
HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO.
HALL LABORATORIES • BRUNER CORP.

pig iron by a top blowing oxygen process.

As shown in Figure 8, a considerable volume a is available in the refining vessel above the slag when compared with the charge of pig iron and the depth of the bath. In the drawing, b is the lance and e the area of impingement of the blast on the layer of slag d on the surface of the bath. The refining gas is blown onto the layer of slag in such a way that during an initial stage of the refining process it will not perforate the skin of slag formed on the bath and not contact the surface of the bath but continuously oxidize the FeO contained in the slag to Fe_2O_3. The Fe_2O_3 thus formed causes dephosphorization at the interface between slag and bath, and is thereby reduced to FeO, but this is again continuously re-oxidized to Fe_2O_3 by the oxygen contained in the blast.

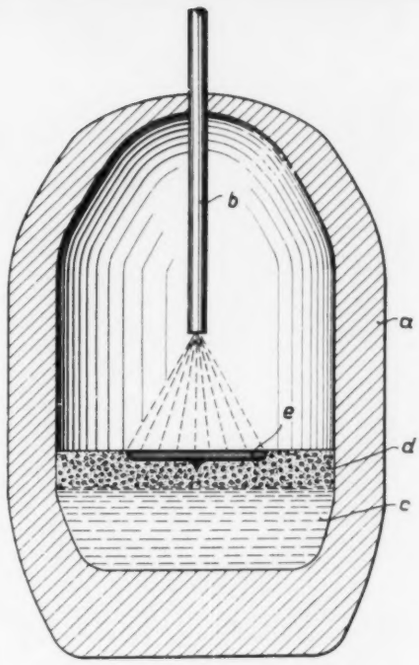


Figure 8

By thus performing the refining process indirectly through the intermediary of the slag, dephosphorization occurs simultaneously with the process of decarburization. The oxidation processes take place intermediately through the oxidizing effect of the slag substantially at the interface between slag and bath by diffusion.

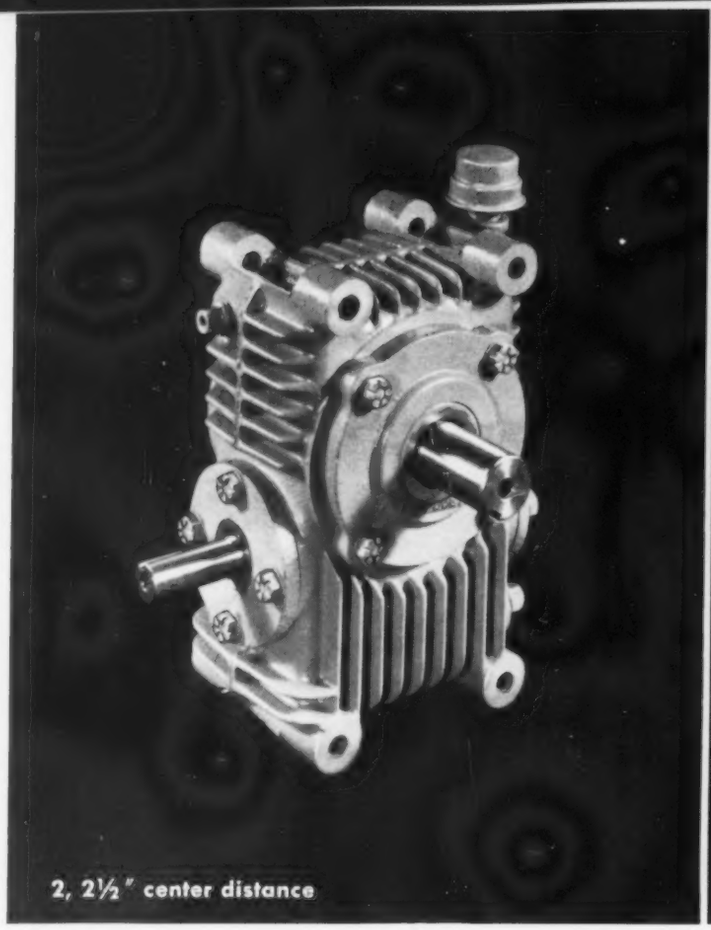
Since decarburization proceeds simultaneously with dephosphorization the slag develops considerable foam as a result of the evolution of carbon monoxide, and foaming is the stronger the greater the surface tension of the slag.

The presence of the foam increases the surface of the slag in a manner which as such is desirable, because it increases the contact area between slag and bath and thus sustains a high rate of depnosphorizing activity.

Therefore, the surface tension is regulated by the addition of borax and fluorides (for increasing the tension) or powdered lime or soda (for reducing the tension).

OTHER PATENTS OF INTEREST TO THE IRON AND STEEL ENGINEER

Patent No.	Date	Subject	Inventor or assignee
2,976,749	3/28/61	Roller guide for rolling mills	Moeller and Neumann G.m.b.H.
2,977,108	3/28/61	Tuyére assembly for a bessemer converter	United States Steel Corp.
2,977,676	4/ 4/61	Ductile-iron welding rod	The Chicago Hardware Foundry Co.
2,977,900	4/ 4/61	Removable covers for railroad cars	Republic Steel Corp.
2,978,219	4/ 4/61	Stove system for blast furnaces	Koppers Co., Inc.
2,978,318	4/ 4/61	Production of steel from pulverulent iron products rich in carbon.	Stora Kopparbergs Bergslags Aktiebolag
2,978,319	4/ 4/61	High-strength, low alloy steels	General Electric Co.
2,978,320	4/ 4/61	High-strength ferrous metal casting	General Motors Corp.
2,978,765	4/11/61	Alloying molten steel as it is poured into an ingot mold	Cleveland Electric Metals Co.
2,979,394	4/11/61	Preparation of high-grade rimmed steel with wide ferritic peripheral zone	Niederrheinische Hutte A. G.
2,979,792	4/18/61	Pouring ladle nozzle seal	United States Steel Corp.
2,979,829	4/18/61	Roller and apparatus for transporting strip material	National Steel Corp.
2,980,291	4/18/61	Apparatus for compounding sinter feed	United States Steel Corp.
2,980,527	4/18/61	Production of ore sinter	Robert W. Strong
2,980,528	4/18/61	Manufacture of rustless iron	Sampei Katakura
2,980,529	4/18/61	Manufacture of aluminum killed steel	American Metallurgical Products Co.
2,980,530-1	4/18/61	Production of nodular iron	The Dayton Malleable Iron Co.
2,980,563	4/18/61	Low remanence high aluminum iron	Westinghouse Electric Corp.



2, 2½″ center distance

3, 3½″ center distance

Custom-build Your Worm Gear Drive from . . .

OVER 200,000 STOCK

The four "worm-under" speed reducers shown above represent only eleven sizes of standard, Cone-Drive units. Also standard are 15″, 18″, 22″, and 24″ center distance units. Cone-Drive worm gear reducers are available in ratios from 5:1 to 4900:1 and up to over 1200 HP capacity. All units feature the double-enveloping principle in which the worm and gear wrap around each other for greatest tooth contact, strength, smoothness, shock-resistance and quietness of operation.

All Cone-Drive worm-gear reducers feature heavy, ribbed, nickel-iron castings for maximum strength and heat dissipation. Heavy-duty taper roller bearings provide anti-friction support to both worm and gear shafts. Chrome-molybdenum-nickel steel worms and tin bronze gears provide long life and high strength. The Cone-Drive design also gives the exclusive benefit that, in service, both gear and worm tend to regenerate their true form . . . worm and gear wear "in" rather than "out."

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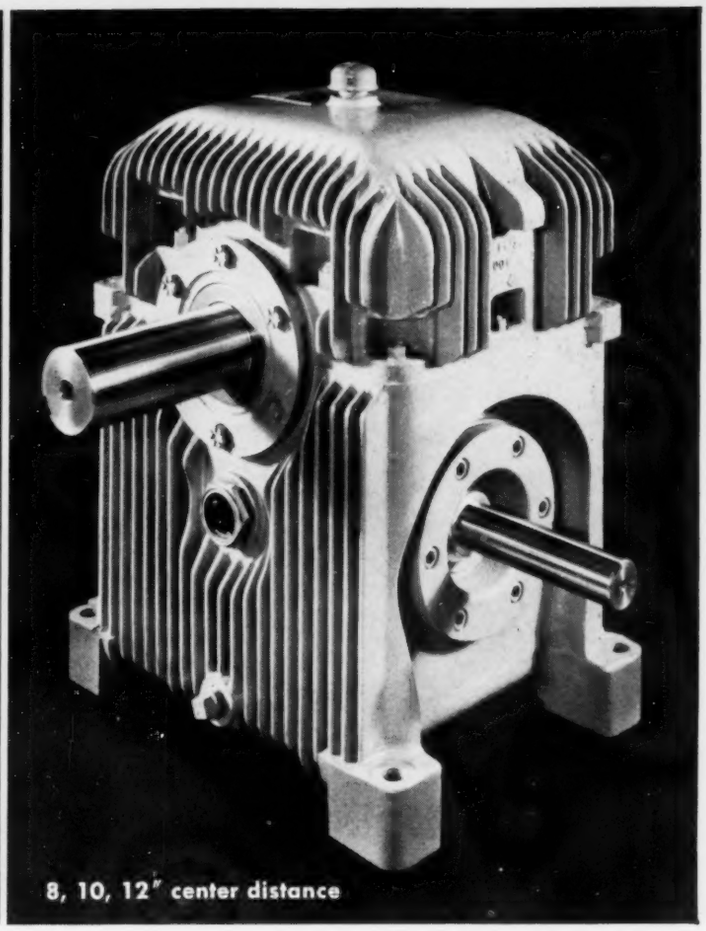
DOUBLE-ENVELOPING WORM GEAR SPEED REDUCERS

DOUBLE REDUCTION WORM GEAR SPEED REDUCERS

DOUBLE-ENVELOPING RIGHT ANGLE GEARMOTORS

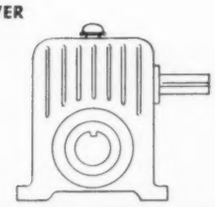
4, 5, 6, 7″ center distance



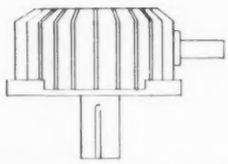
8, 10, 12″ center distance

CONE-DRIVE REDUCERS

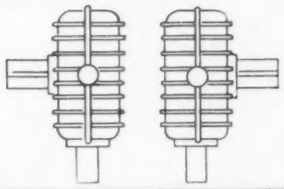
WORM-OVER



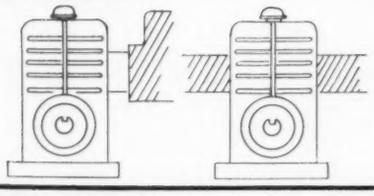
VERTICAL GEARSHAFT



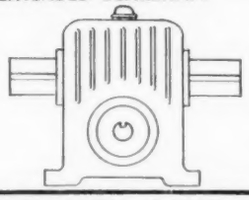
RIGHT- OR LEFT-HAND SHAFT



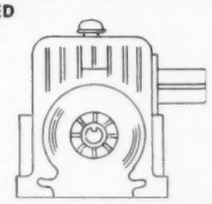
SHAFT MOUNTED



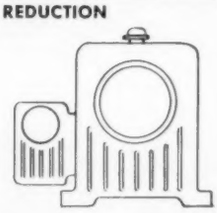
DOUBLE-EXTENDED GEARSHAFT



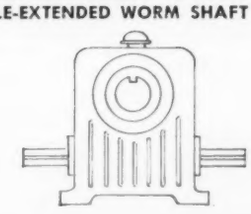
FAN-COOLED



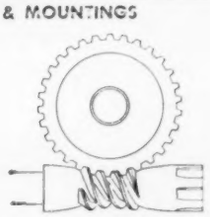
DOUBLE REDUCTION



DOUBLE-EXTENDED WORM SHAFT



GEARSETS & MOUNTINGS



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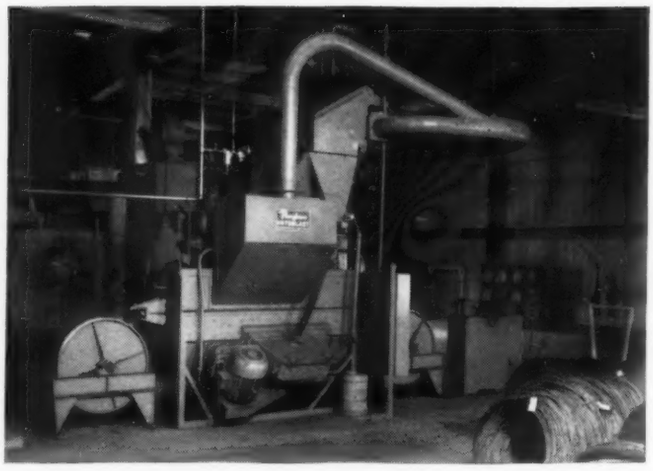

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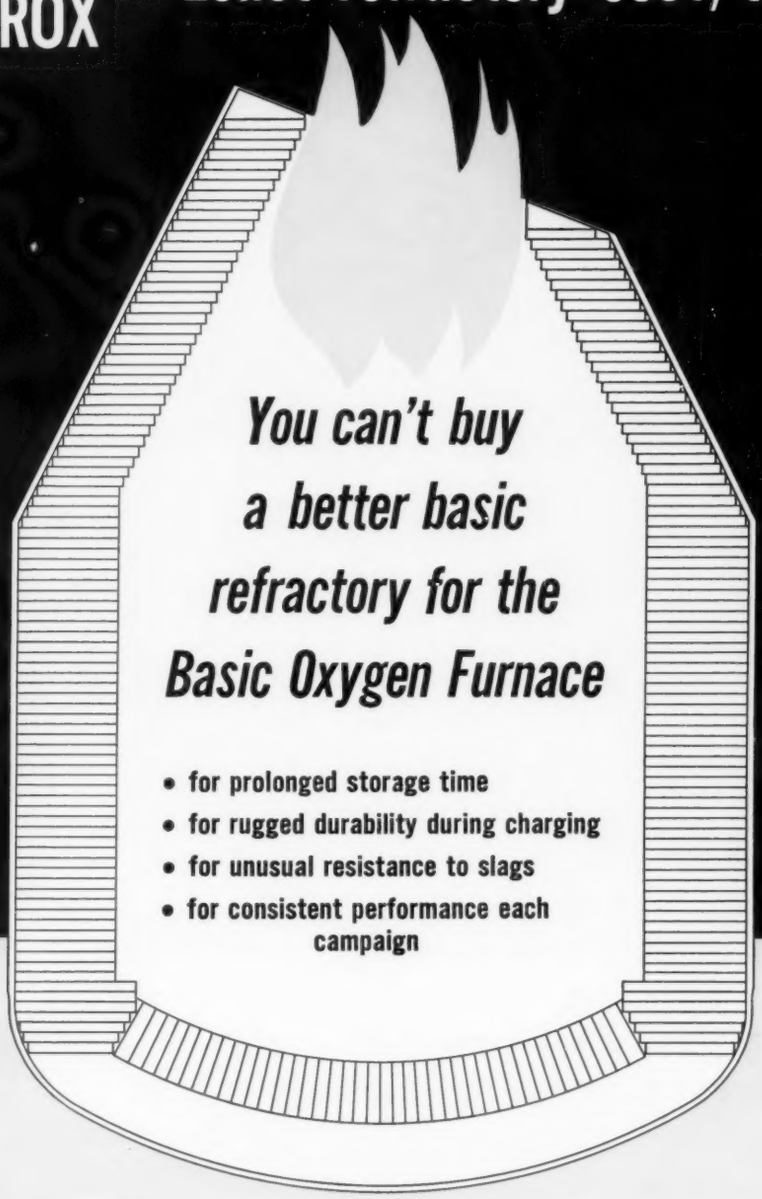

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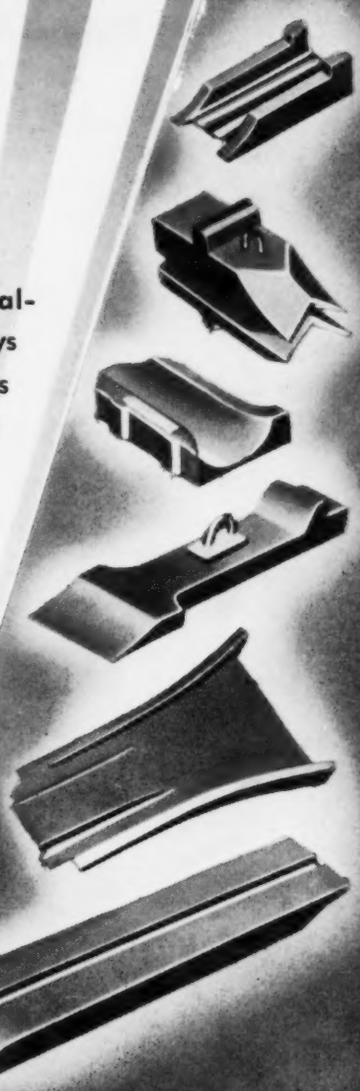

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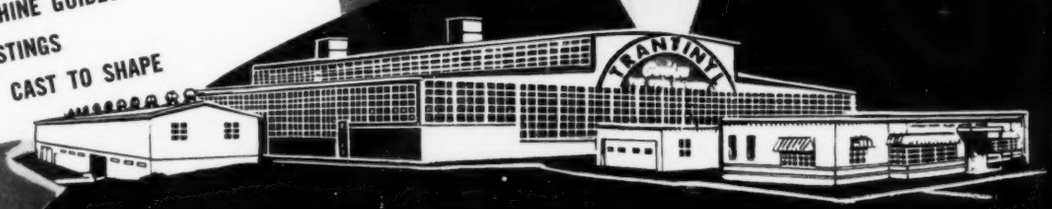

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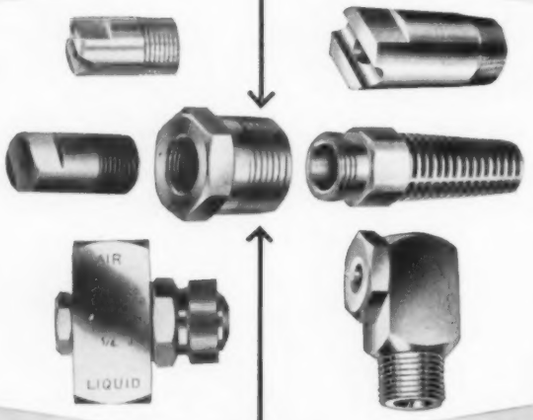

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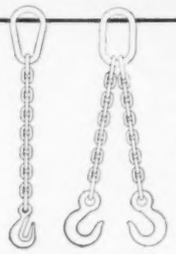

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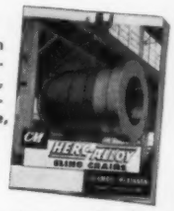

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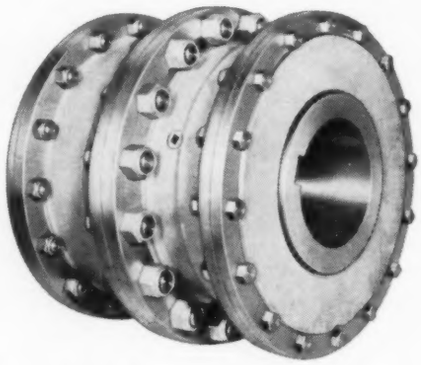

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up to 6,000 hp per 100 rpm

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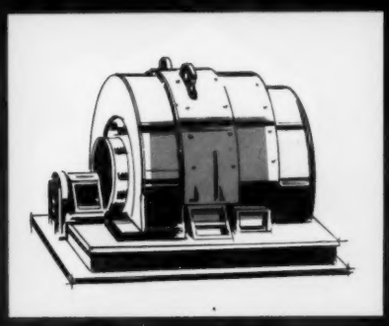
Couplings

STEEL IS ROLLED AT THE HOMESTEAD WORKS WITH AN ASSIST FROM NATIONAL BRUSHES

TRADE-MARK



Rolling mills at the Homestead Works of United States Steel Corporation exert tremendous pressures to squeeze steel into desired thicknesses. The mills are designed to handle terrific mechanical strains ...the motor-generator sets to take the swinging peak loads imposed.

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To help improve electrical operations, we offer a positive carbon brush service program. Just call your "National" Brush Man or write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N.Y. In Canada: Union Carbide Canada Limited, Toronto.

Contact your "National" Brush Man

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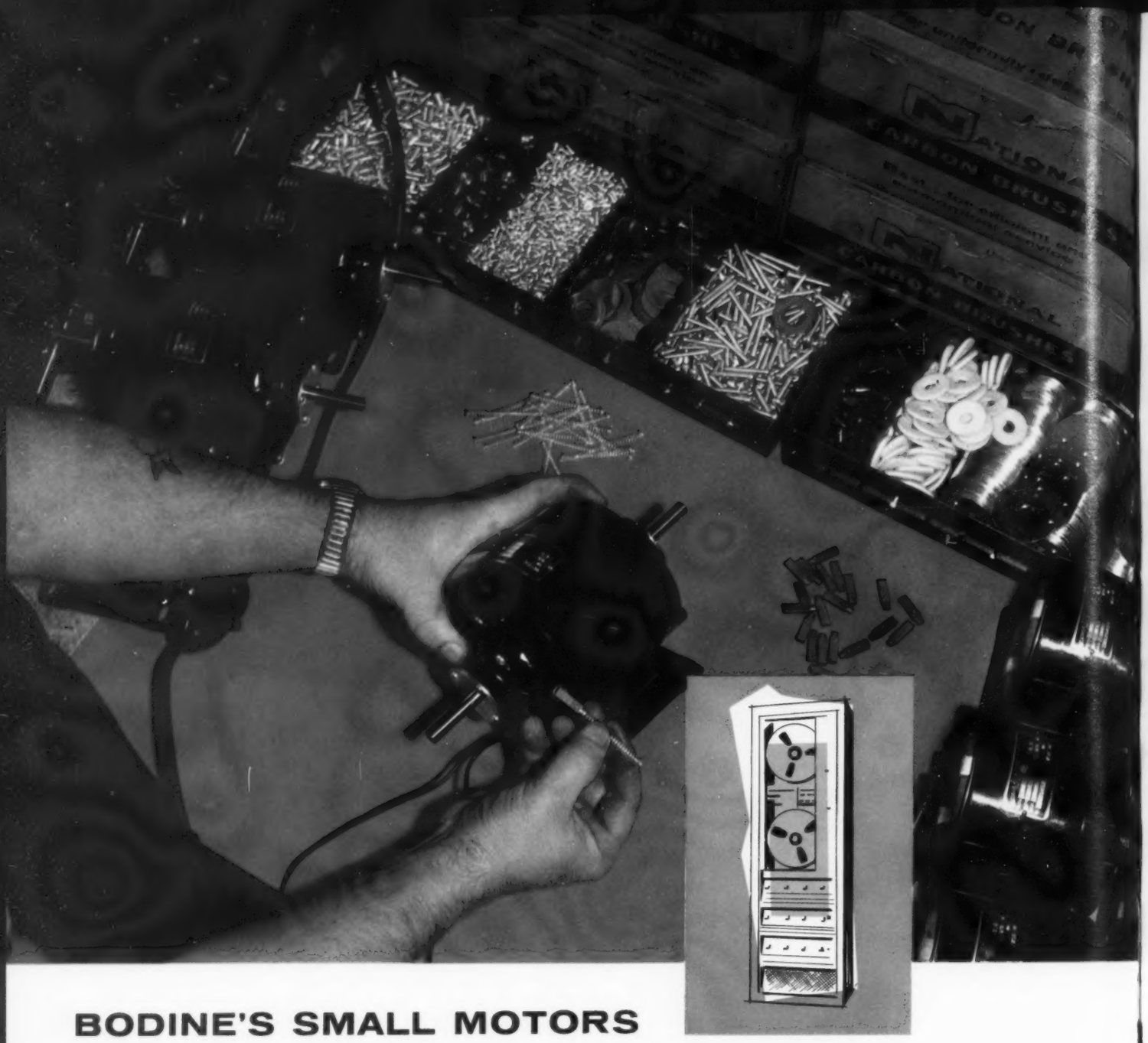

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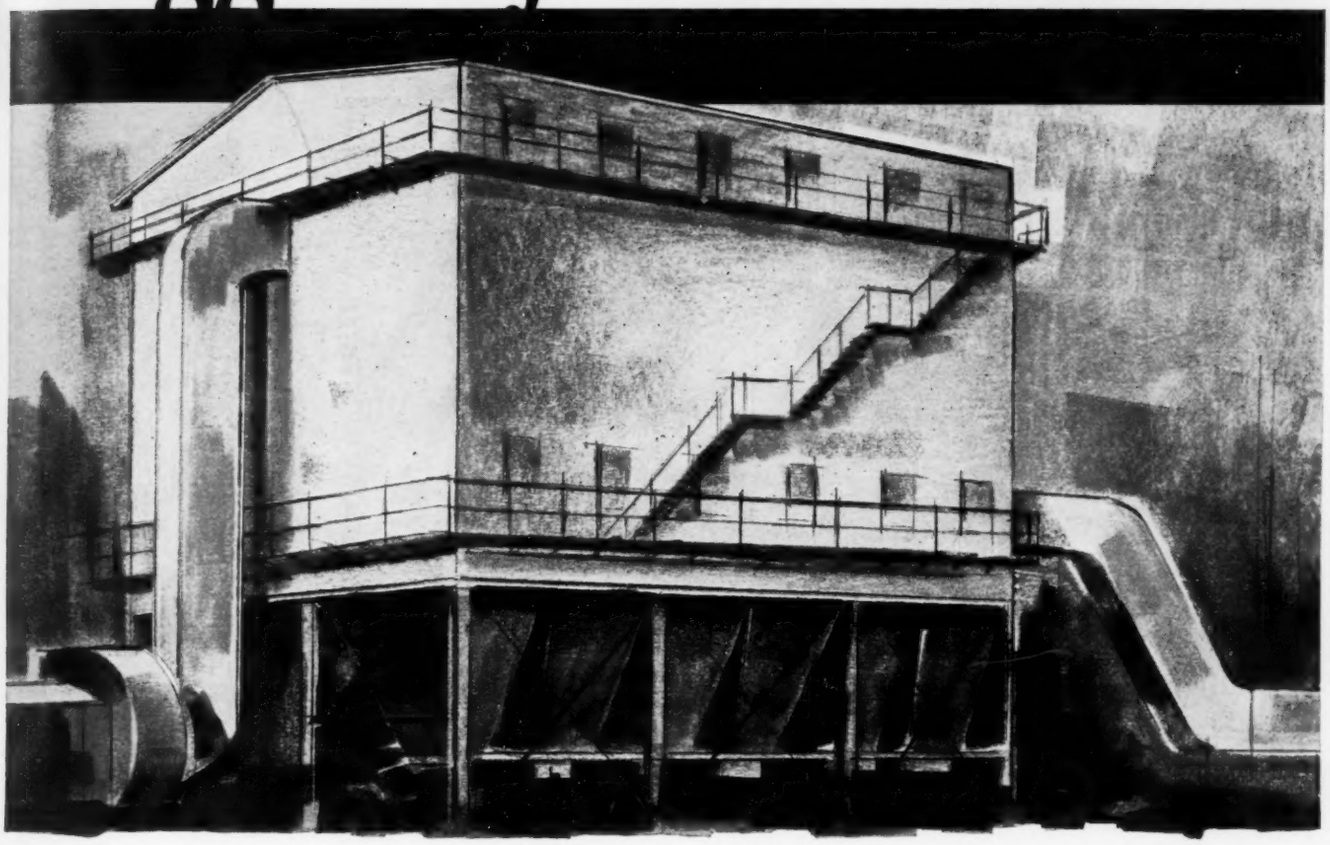

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For open hearths, sinter plants, electric furnaces, cupolas, converters.

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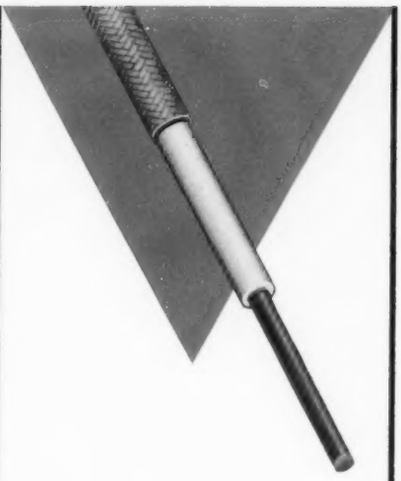
	POWER CABLE	CONTROL CABLE	APPLIANCE and FIXTURE WIRE
Voltage	600 and 5000 volts	600 volt	300 and 600 volt
Operating Temperature	125°C	125°C	150° and 200°C
Size Range	600V: #14 AWG to 500,000 CM 5000V: #8 AWG to 500,000 CM	#14 — #9 AWG	150°C: #22 to #18 AWG — 300 volt #22 to #10 AWG — 600 volt 200°C: #18 to #12 AWG — 600 volt
Construction	**Conductor** — Tinned copper, stranded **Insulation** — Silicone rubber **Covering** — Asbestos braid	**Conductor** — Tinned copper, stranded **Insulation** — 3/64ths silicone rubber, glass braid, color coded **Covering** — Cable tape, asbestos braid. Also available in galvanized steel, aluminum or bronze interlocked armor	**Conductor** — Tinned or nickel plated, stranded or solid **Insulation** — Silicone rubber **Covering** — Glass braid
Applications	Power wiring in high ambient temperature locations. Allows the most efficient utilization of the conductor. Satisfactory for installations in wet or dry locations.	Recommended where control or signal circuits are exposed to high ambient operating temperatures... steel mills, power stations, automotive, cement and glass plants.	For wiring of high wattage units, such as lighting fixtures, clothes dryers, sun lamps, stoves, electronic equipment, water heaters, ovens, and other apparatus.

Wire & Cable Selector



APPARATUS and MOTOR LEAD WIRE	LIGHTING WIRE
600 volt	600 volts
200°C	125°C
#20 to 4/0 AWG	#14 to #8 AWG
Conductor — Tinned copper, stranded **Insulation** -- Silicone rubber **Covering** — Glass braid	**Conductor** — Solid tinned copper **Insulation** — Silicone rubber **Covering** — Glass braid
For leads to motors and transformers in high temperature locations. Stands up excellently under varnish dip and bake processes.	For lighting circuits in high ambient temperature locations.

Rockbestos Silicone rubber cables give you these outstanding advantages:

- excellent heat resistance 125°C-200°C allowable conductor temperature
- flame resistant—slowly forms non-conducting ash maintaining circuit integrity
- corona and ozone resistant
- maintains flexibility from —130°F to +500°F
- excellent resistance to oil, solvents, fuels and chemicals
- excellent electrical properties

ROCKBESTOS WIRE AND CABLE CO.
division of **CERRO CORPORATION**
Nicoll and Canner Sts., New Haven, Conn.

Gentlemen:

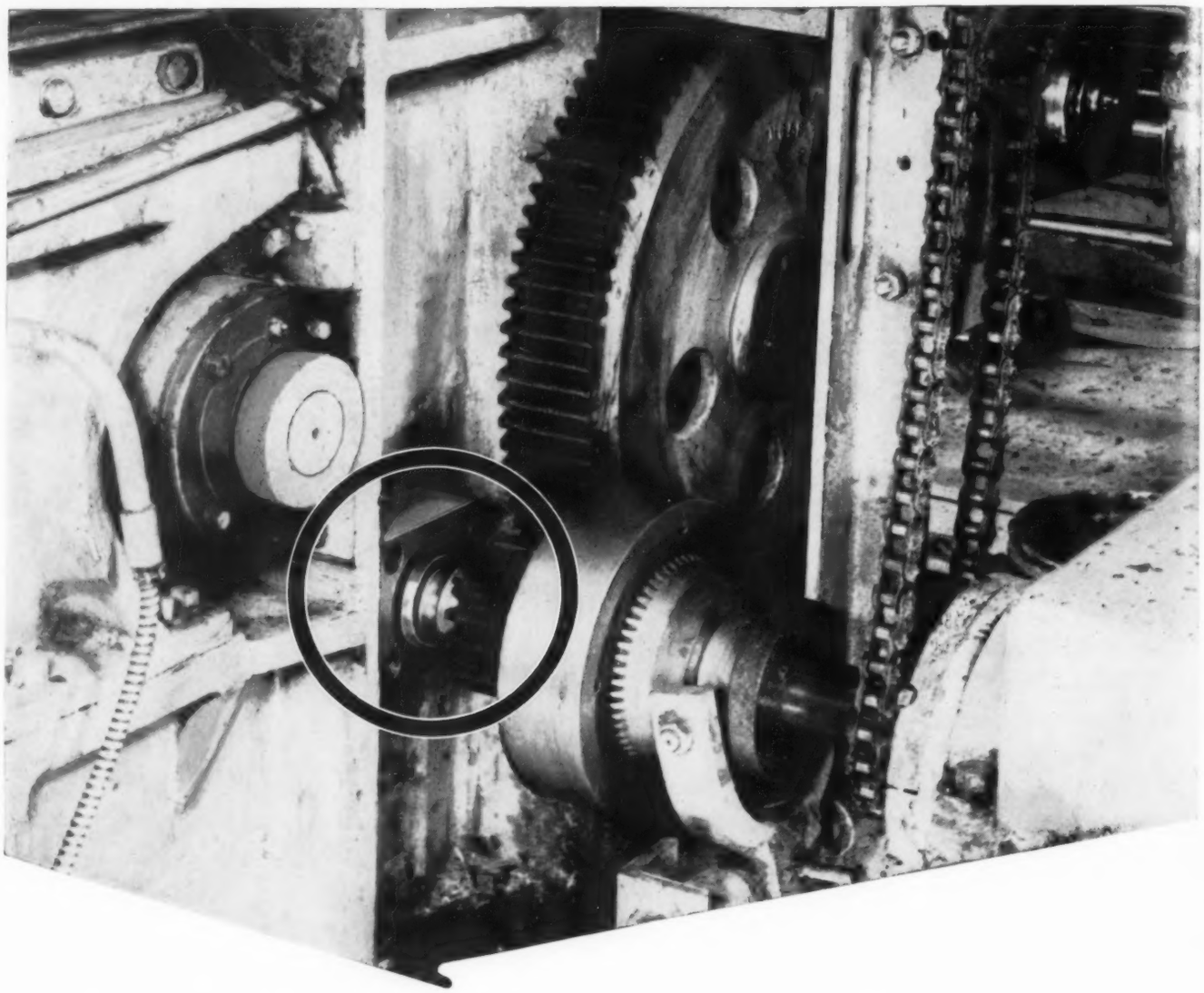
I would like to know more about the unique advantages of Rockbestos Silicone Rubber Wire and Cable. Please send me the following:

- ☐ The Rockbestos Silicone Wire & Cable Catalog.
- ☐ A sample of your silicone rubber wire.
- ☐ Please have distributor or salesman call.

Name_____

Company_____

Address_____



Bearings, Inc. engineers will upgrade your equipment - eliminate early bearing failures!

The original bearings on the pinion drive of this corrugating machine had an average life of only three months. Our customer had been advised that only a complete engineering change of machine drive would solve the problem.

Our engineers refused to accept this verdict and after much research found a standard, double row, roller bearing that, plus a standard adaptor, would fill all dimension requirements and give the radial capacity necessary for trouble-free operation.

We solved this bearing problem (as we have solved countless others) because we are authorized distributors for all nationally-known makes of bearings. We know the characteristics of each type of bearing and our recommendations are backed by many years of experience.

When you need bearings for any purpose, call the branch nearest you. We have the most extensive, the most complete stock of bearings and bearing accessories in the world ready to serve you.

Providing bearing service in the North → **BEARINGS, INC.**

DELAWARE: Wilmington • **ILLINOIS:** Neiman Bearings Co., E. St. Louis • **INDIANA:** Ft. Wayne • Indianapolis • Muncie Terre Haute • **MARYLAND:** Baltimore • **MISSOURI:** Neiman Bearings Co., St. Louis • **NEW JERSEY:** Camden • Newark **NEW YORK:** Balanrol Corp., Buffalo • Niagara Falls • **OHIO:** Akron • Canton • Cincinnati • Cleveland • Columbus • Dayton • Elyria • Hamilton Lima • Lockland • Mansfield • Painesville • Toledo • Youngstown • Zanesville • **PENNSYLVANIA:** Erie • Johnstown • Philadelphia • Pittsburgh • York **WEST VIRGINIA:** Charleston • Huntington • Parkersburg • Wheeling

and

in the South → **DIXIE BEARINGS, INC.**

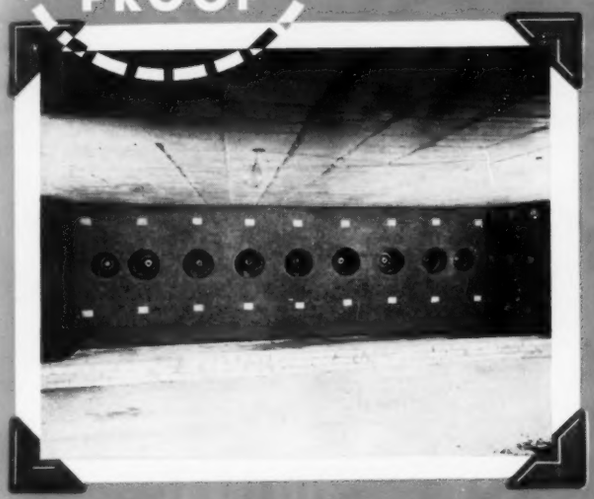
ARKANSAS: Little Rock • **FLORIDA:** Jacksonville • **GEORGIA:** Atlanta • **KENTUCKY:** Louisville • **LOUISIANA:** Baton Rouge New Orleans • **N. CAROLINA:** Asheville • Charlotte • Greensboro • **S. CAROLINA:** Greenville • **TENNESSEE:** Chattanooga • Kingsport Knoxville • Memphis • Nashville • **VIRGINIA:** Norfolk • Richmond • Roanoke

HERE'S UNRETOUCHED PROOF

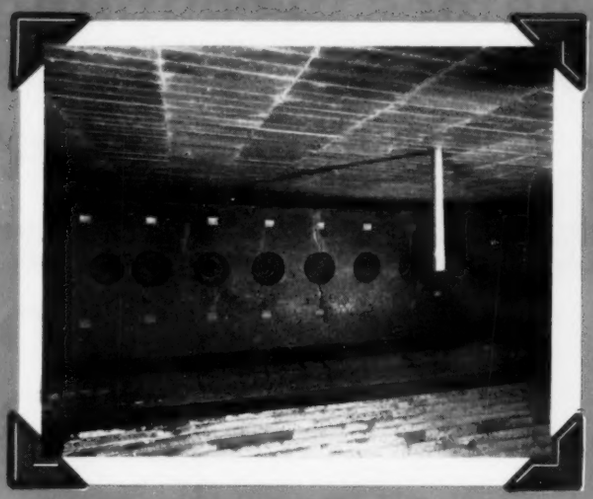
. . . in rail and billet reheating furnace at

INLAND STEEL

Plibrico plastic refractory lining shows how it can take punishment

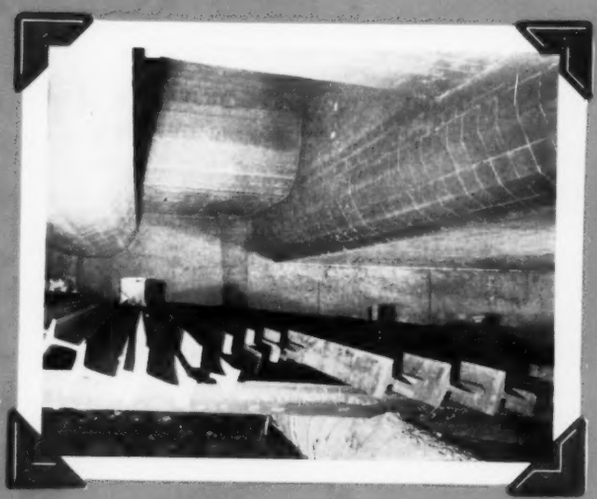


APRIL 1960 . . . view shows front burner wall of rugged, shock-resistant Plibrico Super "F".



TODAY . . . unretouched photograph of same area shows how Plibrico Super "F" withstands punishment in this high heat zone.

APRIL 1960 . . . view at charging end shows sidewall and flared doors also formed with Super "F", a grade for high heat conditions.



TODAY . . . unretouched photograph illustrates Plibrico's tight, stable monolithic lining of Super "F" after almost one year in service.

PLIBRICO OFFERS A WIDE SELECTION of plastics, castables, gunning and ramming mixes formulated to give you exactly the properties and characteristics you need. Get complete data on Plibrico products and their advantages from your local Plibrico man.

REFRACTORIES
INCINERATORS
ENGINEERING
CONSTRUCTION

Plibrico

PLIBRICO COMPANY

1804 North Kingsbury Street, Chicago 14, Illinois

Canadian Plant: New Toronto, Ontario

Sales and Service Throughout the World

Since 1914—Pioneers in Refractory Specialties

1235

CATALOGS 68 & 71 cover plastics, ramming mixes and castables giving advantages and applications.

Three great names in couplings

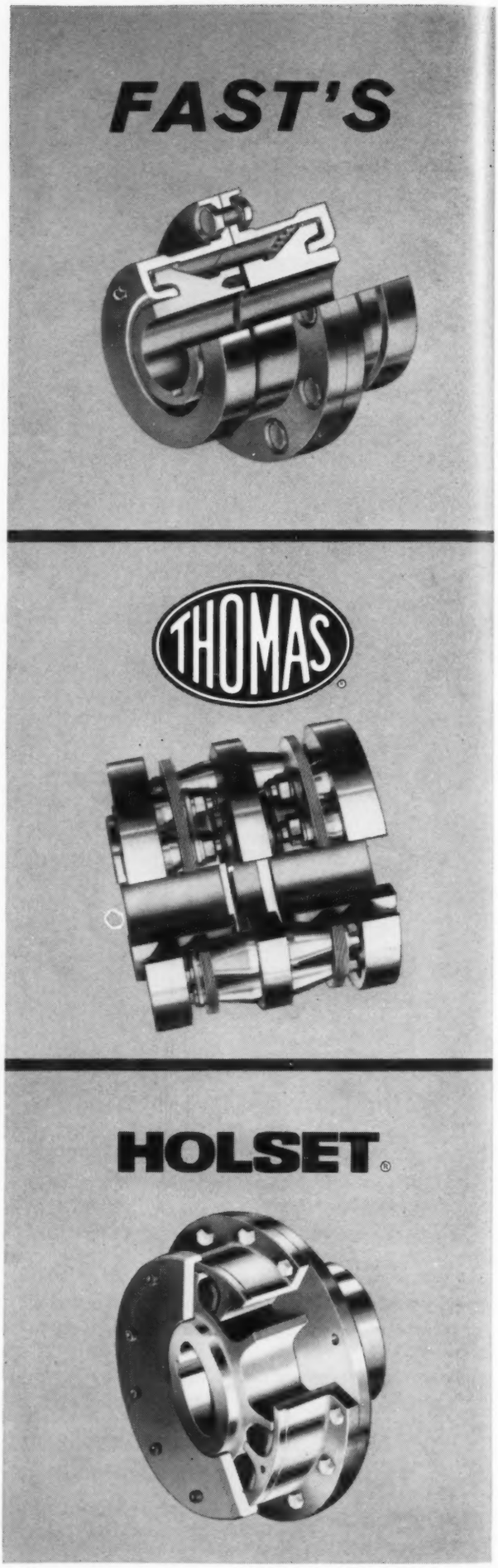
NOW CARRY THIS CORPORATE SYMBOL

KOPPERS®

With the acquisition of the Thomas Flexible Disc Coupling line, Koppers now provides engineering solutions to a wide range of industrial coupling problems. Need a lubricated gear-type coupling for transmitting high loads? Koppers world-famous Fast's coupling line does the job on shafts up to 32 inches. Need a maintenance-free flexible-disc coupling with no backlash? The highly engineered Thomas line holds the answer—with miniature couplings as small as 1/12th of an ounce. Need a coupling to absorb impact or vibration? The Holset line of resilient, non-lubricated couplings protects equipment in most diesel, compressor and shock load applications.

Because each of these coupling lines has its particular application in industry . . . and because each is a recognized name in the power transmission field . . . you can continue to buy them by brand—just as you have in the past. Of considerable importance are the experienced, extensive engineering and manufacturing services of the entire Koppers organization that are available to help you with your power transmission problems . . . in any size, in any quantity, for any use.

KOPPERS COMPANY, INC.
COUPLING DEPARTMENT
Baltimore, Md. • Warren, Pa.
Engineered Products Sold with Service



How to automate step by step

Automation means many things to many people . . . ranging from the simple sequencing of individual operations to the completely automatic system.

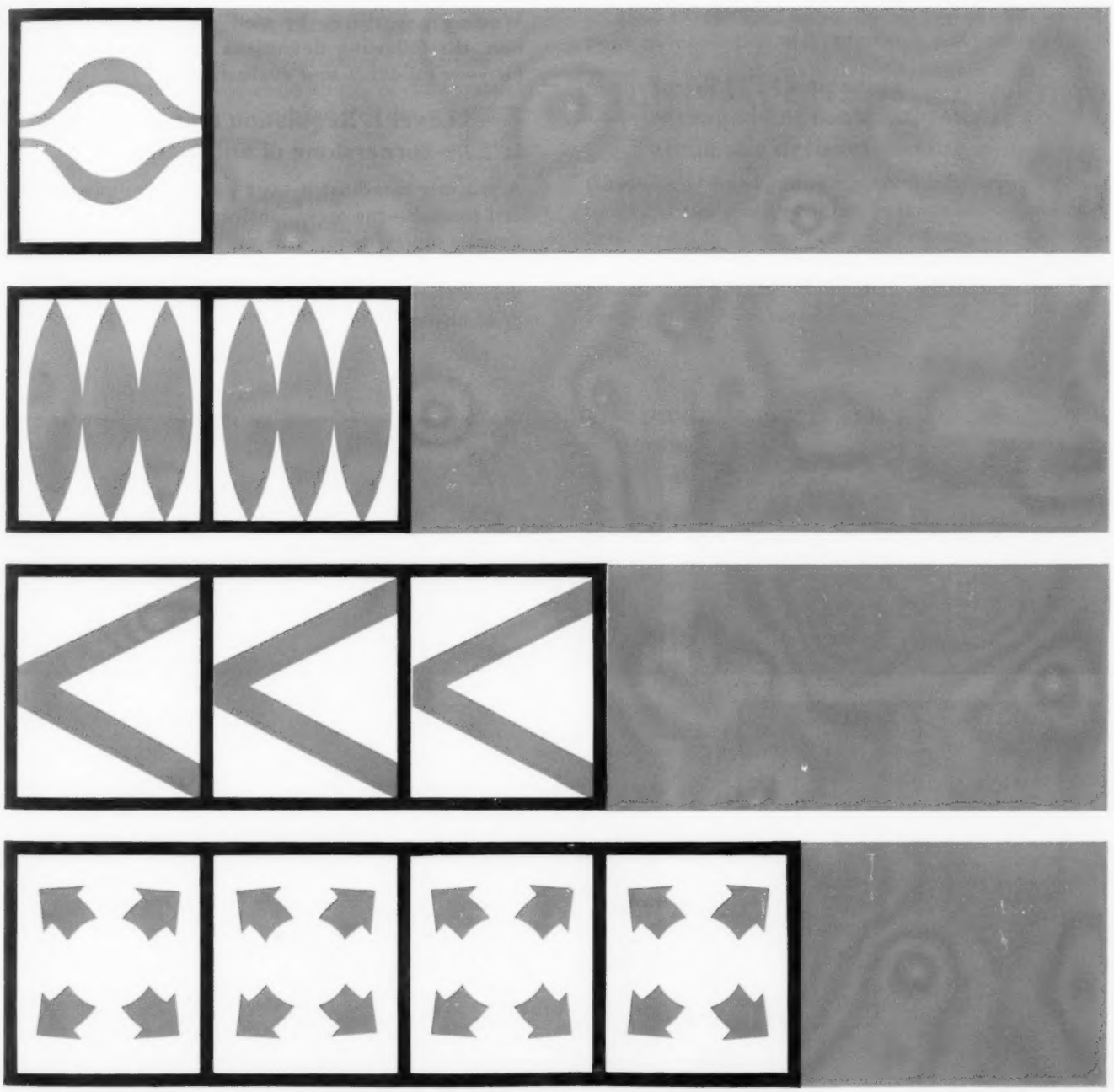
Westinghouse has chosen the term "Progressive Automation" to describe a step-by-step application and coordination of electric drive systems . . . executed in stages that are completely compatible to your cost-reduction, production quality and equipment modernization goals.

Such a step-by-step concept permits you to realize immediately higher mill rates, better steel quality and longer mill equipment life in those individual operations that are initially automated . . . and at the same time, moves you a big step closer to the full profit and production benefits of completely automated facilities.

Westinghouse, the leader in this field, is ready to work with you at whatever level you are currently concerned with . . . from simple process regulation to ultimate continuous decision-making computer control.

What level of Westinghouse's "Progressive Automation" meets your current needs best? Let's examine the definitions on the following pages . . .

Westinghouse

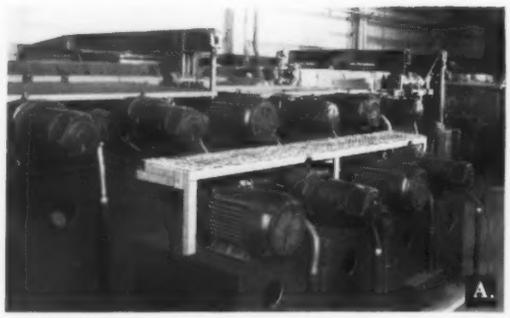


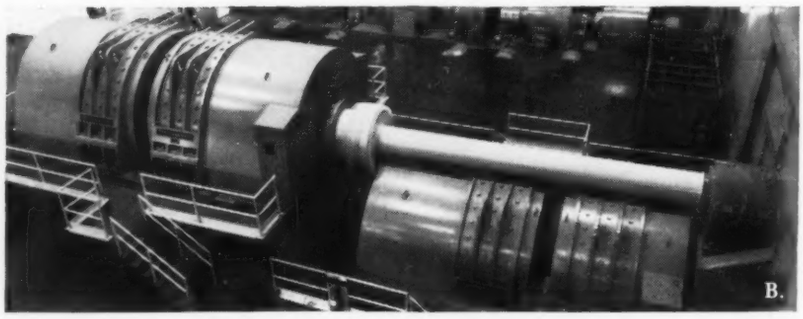
Westinghouse can help you plan the levels best for you . . . apply them as fast as you want

To properly relate your current operations to the Westinghouse "step by step" approach to automation, the following definitions have been developed for your guidance and evaluation:

Level I. Regulation and Gauge Control —cornerstone of automation

A properly coordinated team of power supplies, motors and controls—the operational muscles and brains—continually supervises and corrects process variables such as voltage, tension, speed, torque, position, dimensions and temperatures . . . for better product quality, greater productivity.


A.


B.

D.

E.

Level II. Programming—the right action at the right time automatically

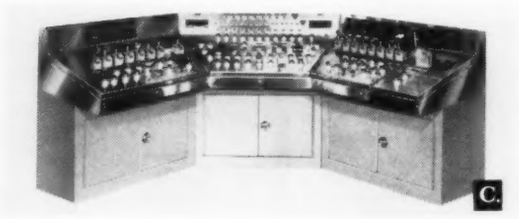
Pre-selection, by means of information contained on punched cards, tapes or manual setups, of the sequence of events and information needed by the regulating system, to control the process.

Level III. Data Logging—fast, precise information

Automatic collection and storage of operating and process information for use when needed—in the form needed. Data logging and display can provide immediate production data for quality control, etc., can record information required to re-program, and can operate as part of a computer in monitoring and optimizing mill performance.

Level IV. Computing—management control through automatic decision making

Continuous decision-making computer control which optimizes the mill operation by constantly monitoring and correcting the programming and regulatory systems. These corrections are required because of changes in process elements, environmental conditions, equipment loading, and other variables.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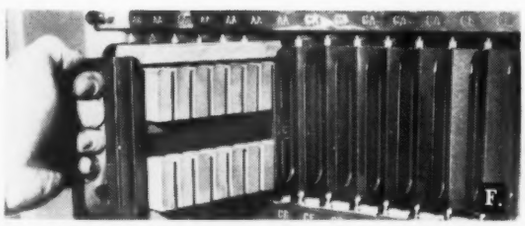
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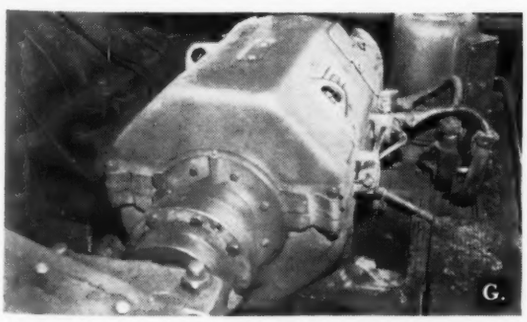

G.

Westinghouse products permit you to realize optimum results at every level of automation

A. Westinghouse Life-Line® motors and Moduline® gearing installed in cleaning section of 50-inch continuous annealing line.

B. Mill muscles are dependable Westinghouse motors with exclusive Thermalastic® insulation on armatures. This 12,000-hp twin drive is conservatively rated . . . designed for rugged rolling mill duty.

C. Typical operator's control pulpit for computer controlled mill.

D. Input portion of data accumulation system with manual switches on left—punched card reader on right.

E. Complete automatic mill operation is possible with Westinghouse on-line industrial Prodac* control computer.

F. Prodac module, representing a circuit function, is easily accessible for removal or replacement.

G. Westinghouse heavy-duty d-c mill motors provide power for toughest applications. On steel mill screwdowns, improved field coil design adds more copper for greater capacity and longer life.

For other considerations affecting your use of Westinghouse *Progressive Automation*, see the next page . . .

*Trademark

Westinghouse

How to apply Progressive Automation to your mills

Exactly where and how can you begin to blue-print your over-all automation plan that will reap all these benefits for your production? The best answer is to begin with the best qualified scource: Westinghouse, who has designed, built and installed more automatic production systems in steel mills than any other manufacturer.

Westinghouse—one source, one responsibility

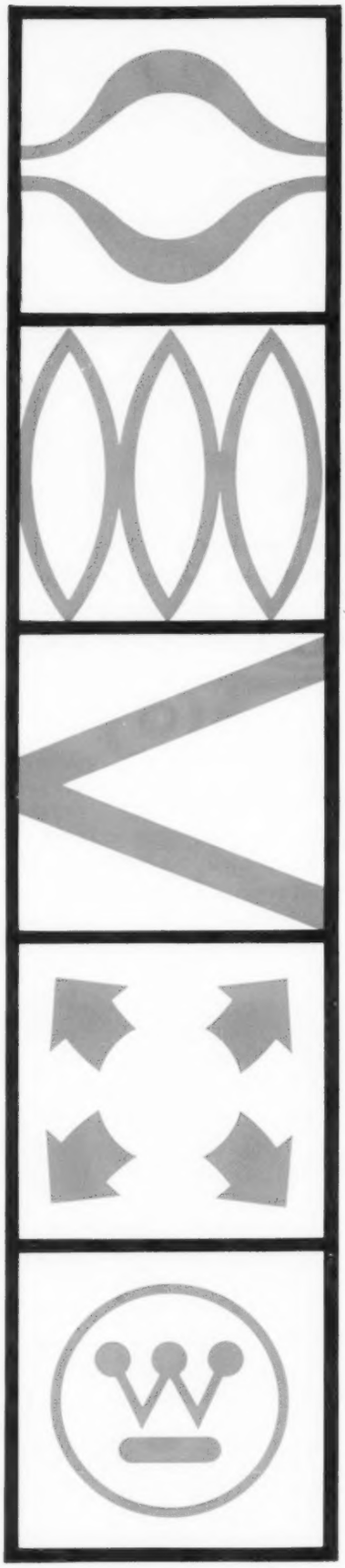
Westinghouse experience, facilities, engineering talent and equipment add up to your assurance of:

1. A sound analysis of your automation needs to determine the automatic systems best suited to your processes.
2. A coordinated systems approach of motors and controls, thoroughly engineered and completely tested, which integrates the stages of automatic production you need.
3. An automatic control system designed for application to your mill in line with the Westinghouse concept of *Progressive Automation.*
4. The use of the latest automation techniques and components—all adaptable to future developments and needed expansion.
5. A single source, a single responsibility for complete automation systems and related electrical equipment.

These complete Westinghouse facilities are available to you. Call your nearby Westinghouse representative, or write Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh 30, Pennsylvania.

You can be sure . . . if it's Westinghouse

Westinghouse



Interested in more information on Westinghouse Progressive Automation for the steel industry? Write for B-8220, a complete set of new brochures describing Automation "steps" in detail as they relate to steelmaking operations. You can reserve a set for your use by indicating your area of interest on your company letterhead and mailing it to: Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh 30, Pa.

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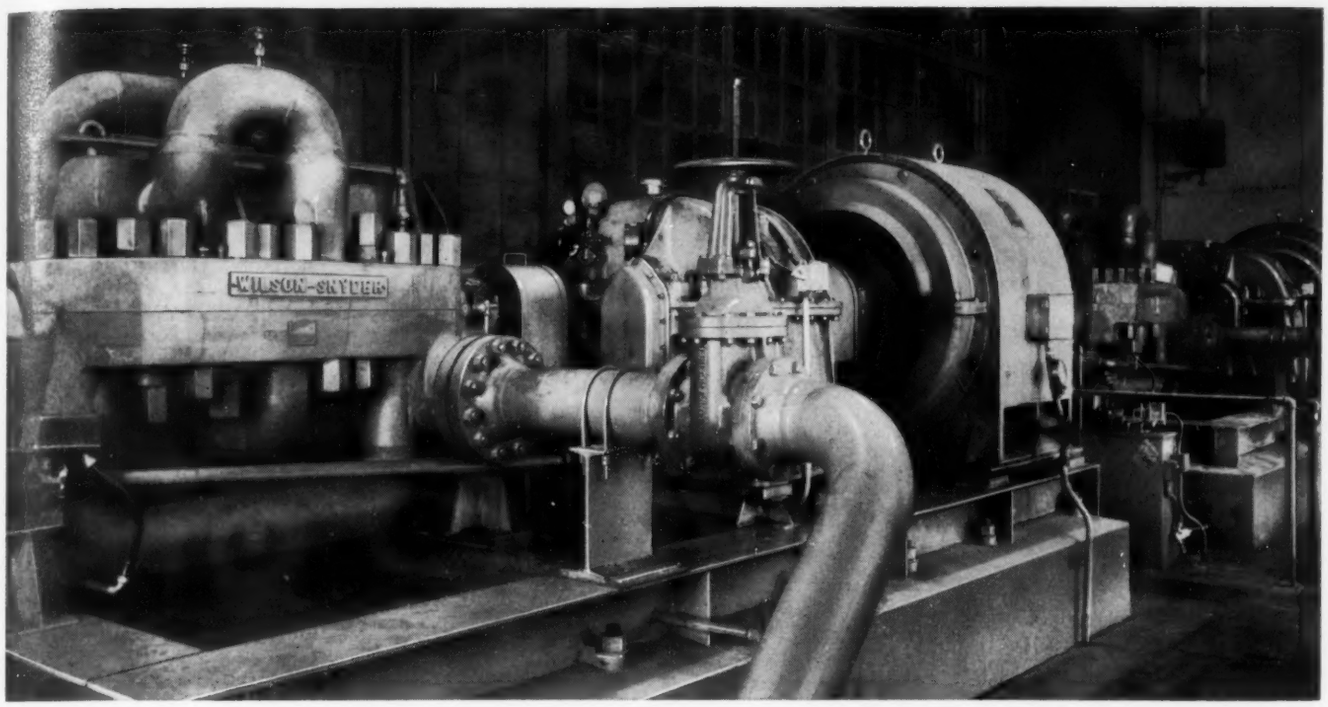


Ford uses Wilson-Snyder High Pressure Descaling Pumps in modernized hot strip mill

Shown above are two Wilson-Snyder heavy duty 6-stage 3,900 RPM centrifugal pumps in Ford Motor Company's modernized hot strip mill. Driven by 2,000 HP, 1,800 RPM motors through speed increasing gears, these powerful pumps deliver water in excess of 1,600 psig to five locations in the mill, two of which have double spray headers top and bottom. This is one of the highest pressure descaling installations in operation anywhere.

Wilson-Snyder also makes complete line of reciprocating pumps

For relatively lower capacities and discharge pressures to 10,000 psi., Wilson-Snyder has a complete line of reciprocating pumps which includes triplex and quintuplex single-acting plunger types, as well as duplex double-acting pumps. These pumps are extensively used in hydraulic system applications and low capacity descaling operations.

Whether you are planning a complete modernization program or new construction, Wilson-Snyder welcomes an opportunity to work with you. We have the engineering "know how" and the experience to save you time and money in selecting and setting up a modern, efficient descaling system. We are prepared to furnish and install the complete system, including the accumulator, charging compressor, headers, strainers, nozzles, spray valves and other necessary components.

We invite your inquiry and will be pleased to quote on your particular requirements. Write or call Wilson-Snyder Works, Oil Well Supply Division, United States Steel, Braddock, Pennsylvania, or your nearest Wilson-Snyder representative.

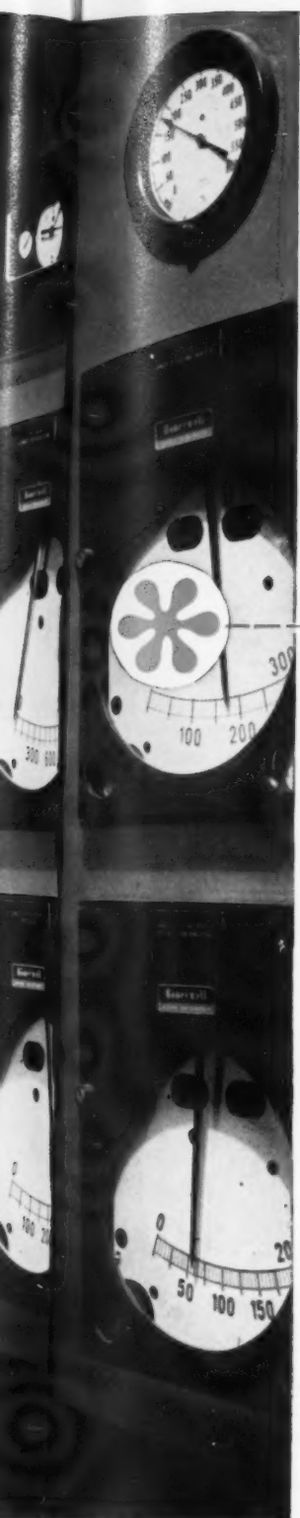
USS, Wilson-Snyder and Oilwell are registered trademarks

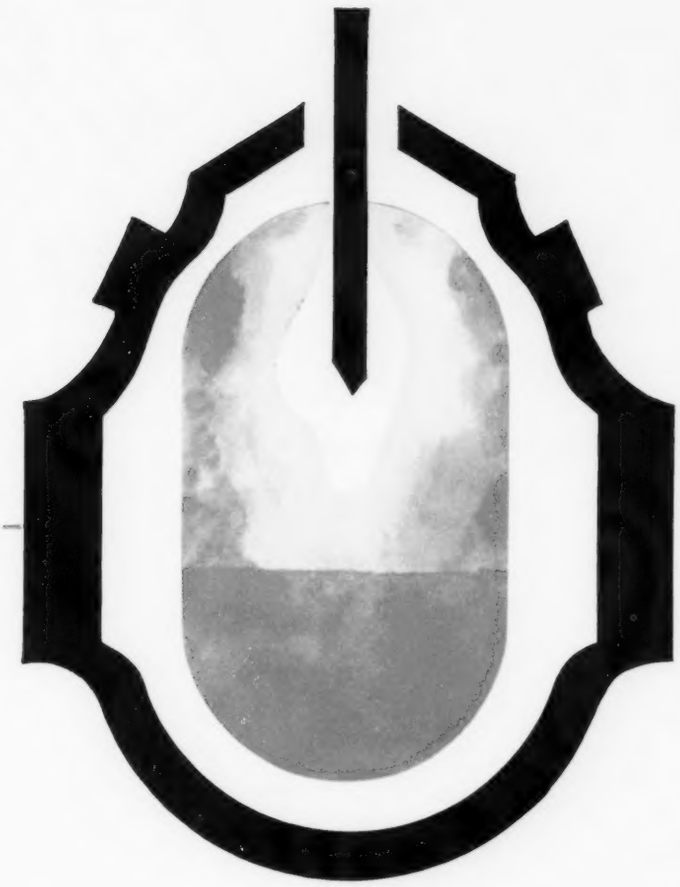
Wilson-Snyder sales engineers . . . at Chicago, Illinois . . . Dallas, Texas . . . Houston, Texas . . . Los Angeles, California . . . New York, N. Y. . . . Tulsa, Oklahoma . . . Pittsburgh, Pa. . . . can furnish you with complete information on this new line . . . or call on your nearest "Oilwell" representative.

This mark tells you a product is made of modern, dependable Steel.

Wilson-Snyder Works
Oil Well Supply
Division of
United States Steel

At Kaiser Steel Corporation, Fontana, California, this Honeywell system helps double plant capacity by controlling oxygen mass flow, lance position, lance cooling water temperature and pressure, and other critical variables. At left, an operator watches charging of one of the three new oxygen converters from a window in the control pulpit.





Why did Kaiser select Honeywell instrumentation for its L-D process?

At the Fontana plant of Kaiser Steel Corporation, Honeywell instruments were selected for the new basic oxygen steelmaking shop. This new process required instruments that were accurate, reliable, and fast enough to deliver the precise integrated control needed.

Kaiser Engineers called on Honeywell to furnish the necessary control instruments.

If you're planning to use the oxygen process—in converter or open hearth—you'll find it profitable to have Honeywell design your entire control system, complete from primary elements to computer, and tailored to the particular requirements of your mill. Your nearby Honeywell field engineer can give you complete details. Call him today—he's as near as your phone.

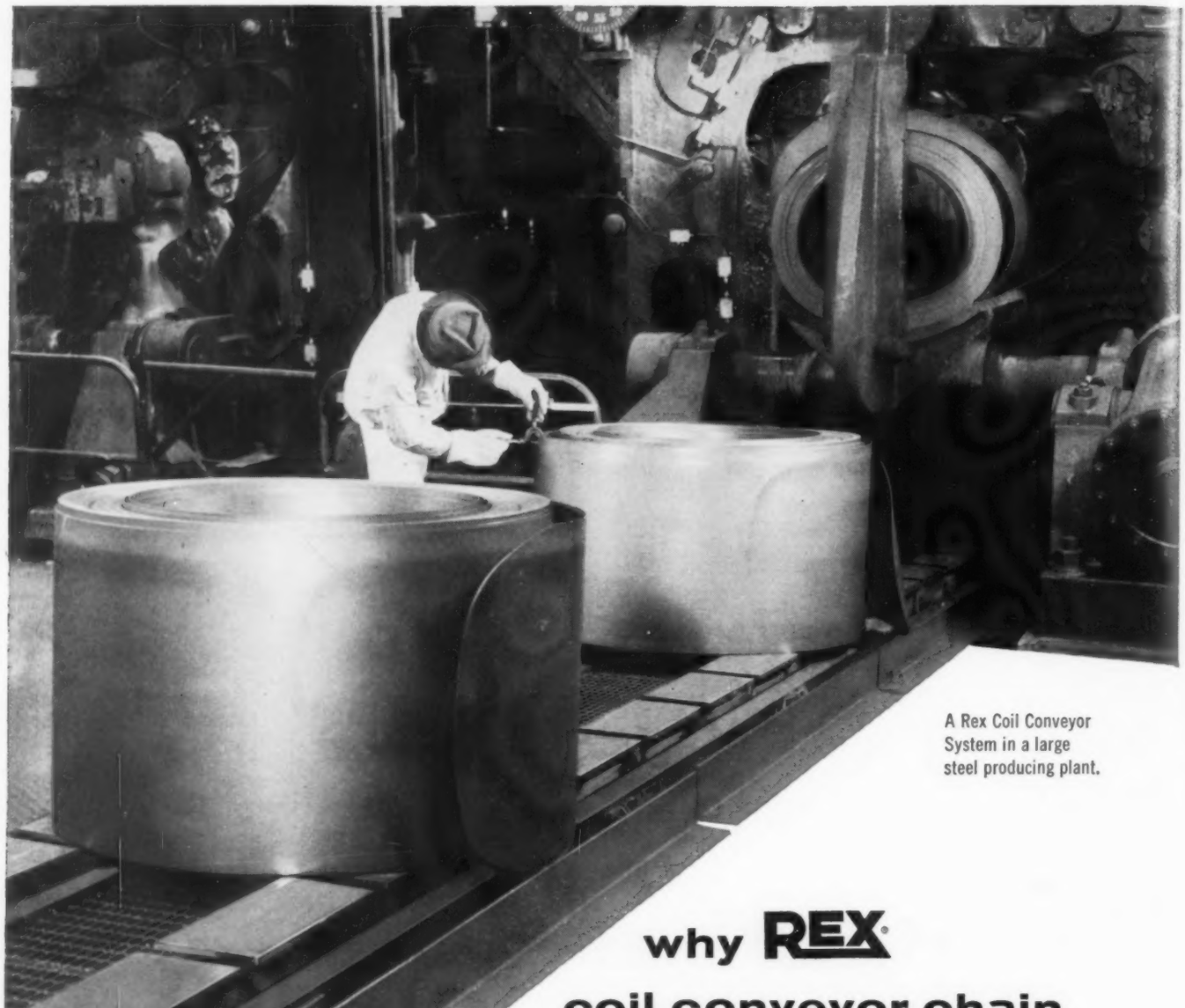
MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



A Rex Coil Conveyor System in a large steel producing plant.

why REX® coil conveyor chain keeps DOWN TIME down

Years of dependable service in many rugged mill applications is proof that Rex Coil Conveyor Chain is a top runner in slashing down time and maintenance costs.

Reason is this: Rex engineers were not satisfied with a "me too" chain. They turned to basic research to give this chain the ability to take it. They selected the materials and the design that would assure the most efficient combination of strength, wear life and economy—used heavy-duty antifriction roller chain to supply smooth operation—attached rugged platforms for a steady, level carrying surface. And over 70 years of CHAIN Belt manufacturing experience, plus rigid quality control, makes sure Rex Chains perform as planned.

Write CHAIN Belt Company, 4693 W. Greenfield Ave., Milwaukee 1, Wis. In Canada: Rex Chainbelt (Canada) Ltd., Toronto and Montreal.

REX®
CHAIN BELT COMPANY

REX IS BEST . . . IN THE USER TEST

28 MORE HOT STRIP MILLS SINCE 1955 HAVE GONE TO

ALGOMA STEEL
ALPINE MONTAN
AUGUST THYSSEN
COLVILLES
CRUCIBLE STEEL – MIDLAND
DOMINION FOUNDRIES & STEEL
DOMNARFVETS
FORD MOTOR COMPANY
FUJI IRON & STEEL
FUNDIDORA
GREAT LAKES STEEL
GUSTAVE BOEL
HINDUSTAN STEEL
KAWASAKI IRON & STEEL (2)
KLOECKNER WERKE
REPUBLIC STEEL – GADSDEN
REPUBLIC STEEL – WARREN
RICHARD, THOMAS & BALDWINS
SALZGITTER
SOCIEDAD MIXTA SIDERURGIA ARGENTINA
SUMITOMO METAL INDUSTRIES
TOKAI IRON & STEEL
USIMINAS
USINOR – DUNKIRK
WESTFALENHUETTE
YAWATA IRON & STEEL
YOUNGSTOWN'S CAMPBELL WORKS

Such overwhelming preference—by wide ferrous hot strip mills—proves the essential soundness of **MORGOIL** design simplicity and manufacturing precision. Regardless of speed or load, this bearing has shown the outstanding record for dependability, long life and cost-saving performance in every area of operation. Backed by the foremost name in steel-making equipment, it is the acknowledged standard of an industry.

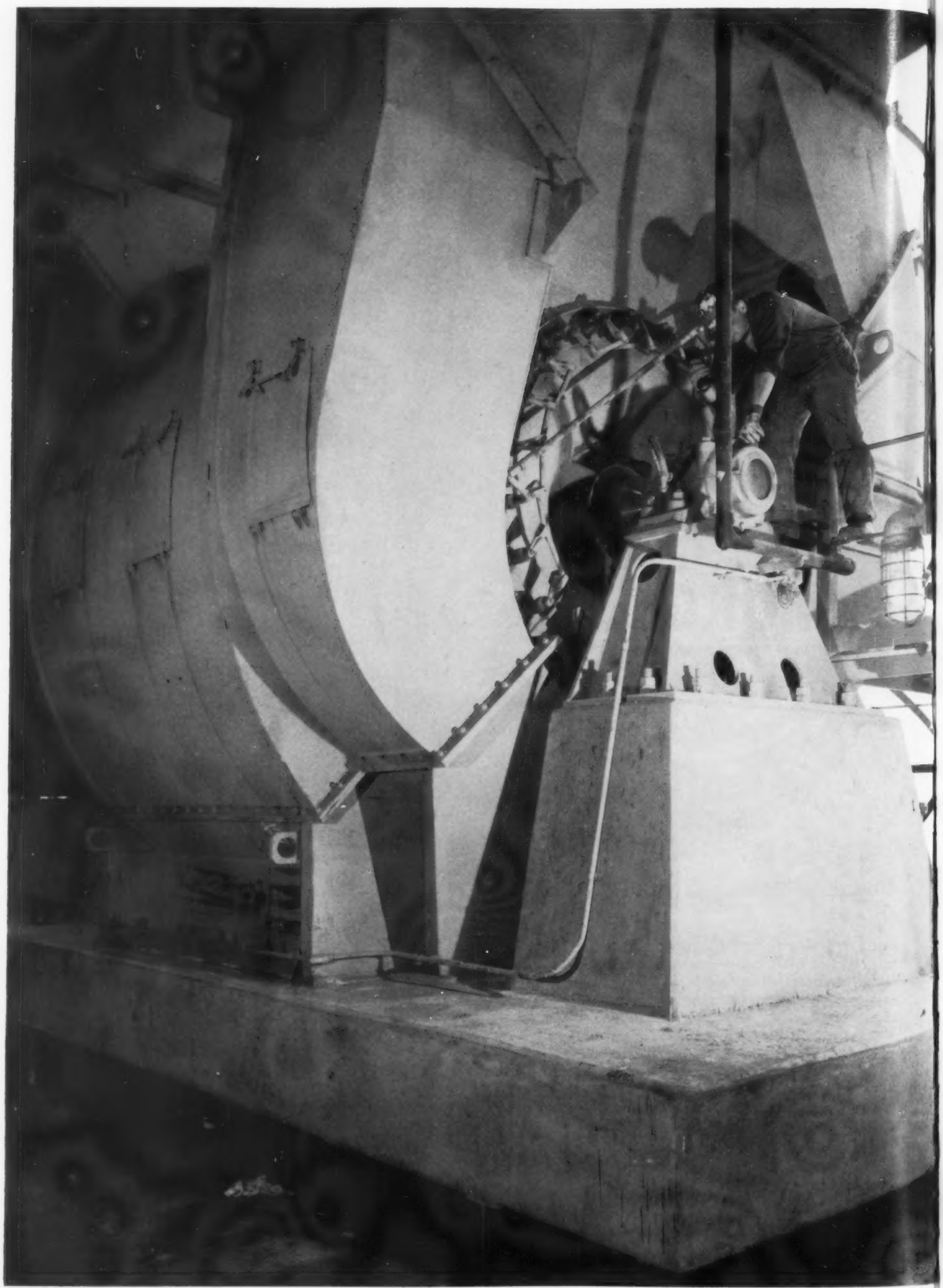
PARTIAL LIST OF INSTALLATIONS SINCE 1955

44 © 1961

MORGAN WORCESTER

MORGAN CONSTRUCTION CO.
WORCESTER, MASSACHUSETTS

ROLLING MILLS • MORGOIL BEARINGS • WIRE DRAWING MACHINES • COMBUSTION CONTROLS



RD Fan used for induced draft on basic oxygen furnace of large steel producer. There are four identical units, each producing 325,000 cfm against a static pressure of 15" wg at 550° F.

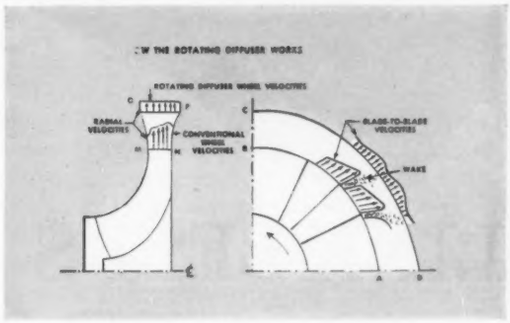
JOY RD FANS CAN PROVIDE PRESSURES UP TO 4.5 PSI AND CAPACITIES UP TO 600,000 CFM

Joy RD Centrifugal Fans, based on a new concept in fan design, can provide any volume of air or gas at pressures up to 4.5 psi in a single stage. This means important savings in initial cost. An equally important saving is their high efficiency over a wide range of volume, which is especially important where load fluctuates. Surging, even on parallel operation, is no problem because the RD Fan is inherently resistant to pressure surge over its entire duty range.

These advantages of the RD Fan are the results of its unique rotating diffuser. Instead of stationary diffusers, the RD diffuser is an integral part of the wheel—added at the blade tips. The rotating diffuser reduces the gas velocity before leaving the wheel and up to 98% of the conversion of velocity to pressure is accomplished with the wheel of the RD Fan.

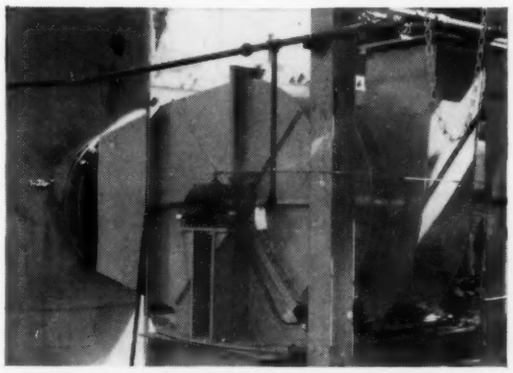
Radial blades in the RD Fan tend to be self cleaning, even when handling dust laden and dirty gases. The rotating diffuser results in low noise levels because of the lower and more regular velocities leaving the wheel and because the blade tips are remote from the cut-off.

The Joy RD Fan is finding steady acceptance in induced draft and forced draft applications in the steel and power industries, in handling chemical process gases, and in heavy duty industrial applications. For extremely dirty or corrosive applications the entire unit may be fabricated of stainless steel. Parts are simple because there are no large castings or close running tolerances. For complete information and duty areas of the RD Fan, write for bulletin 3449-68.



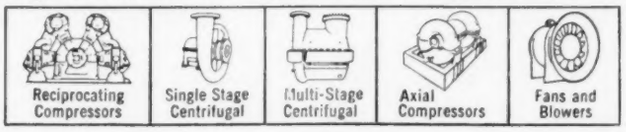
HOW THE ROTATING DIFFUSER WORKS

Studies have shown that radial velocities leaving conventional wheels are unequally distributed, as shown in MN. Also there is fluctuation in the blade-to-blade velocities based on $\frac{nN}{60}$ where n is the number of blades and N is the speed in rpm. The Rotating Diffuser reduces the gas velocity before leaving the wheel, which allows more uniform flow as shown at OP and CD. Without the rotating diffuser, velocities are much higher and erratic as shown at AB and MN, causing turbulence, friction losses.



Joy RD Fan at eastern CO_2 plant. Unit has capacity of 27,800 cfm, at 3 psi. Drive is a 450 hp steam turbine.

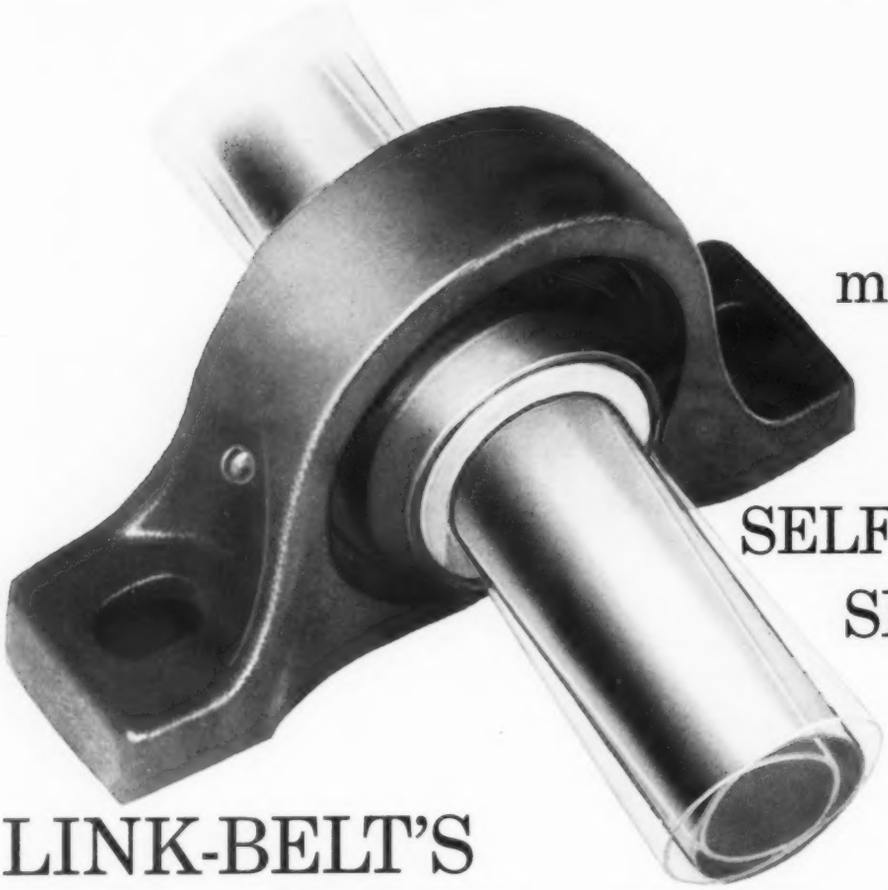
AIR MOVING EQUIPMENT FOR ALL INDUSTRY



JOY

Joy Manufacturing Company
Oliver Building, Pittsburgh 22, Pa.

In Canada: Joy Manufacturing Company (Canada) Limited, Galt, Ontario



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maintenance
2 ways--it's
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New Link-Belt self-aligning Flex-Block sleeve bearings compensate for shaft deflection and misalignment. They keep shafts turning freely . . . assure full load capacity under severely corrosive and contaminating conditions—even under water! And eventually the bearing cartridge can be rotated 180° to present an unused bearing surface, extending useful service life. Turning the cartridge can be accomplished without removing bearing from shaft. Flex-Block is also ideal for applications requiring quiet or low-speed operation . . . and for inaccessible locations, since there is practically no need for maintenance.

Flex-Block bearings are immediately available in pillow- and flanged-block types, for shaft diameters from ⅝ to 3-15/16". Several types of sleeve materials are offered to accommodate temperatures up to 1000 F and a wide variety of load conditions. Get details on Flex-Block bearings from your nearby Link-Belt distributor, or write direct for Folder 2823. Ask also about Link-Belt's complete line of other quality bearings, including babbitted, bronze, ball and roller bearings for every application. 15,682

Self-aligning flanged-block sleeve bearings

Self-aligning pillow-block sleeve bearings

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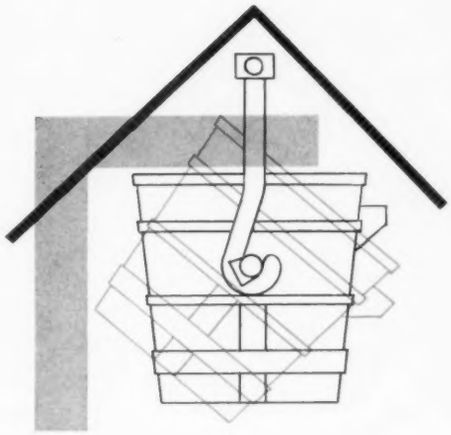


STEEL ANGLES

IN THE discussion on foreign imports a new and interesting element has been added in the form of a brief booklet issued by the Brown Boveri Corp. This attempts to make a strong case in favor of imports. The company, located in Switzerland, imports through its subsidiary in the United States, a considerable amount of heavy electrical and mechanical power equipment. In fact it is the principal importer in this field, doing business in the United States for 35 years. Under these circumstances, it is understandably concerned over the unfavorable publicity given foreign imports during the past few years, and has been especially disturbed by the "Buy American Campaign."

The book stresses general arguments in favor of foreign trade. It points out that although the United States has had an unfavorable balance of payments for a number of years, it has had a favorable balance of trade. For example, in 1960 this country imported $15,000,000,000 worth of goods, while exporting $20,000,000,000. The booklet quotes people, beginning with President Kennedy, who have declared that protectionism is no solution to the problem of foreign competition.

The study asserts that all competition, either foreign or domestic, is a benefit to the economy of the United States. It maintains that "anyone who believes in the value of competition must logically believe also in the value to the domestic economy of imports, since imports are merely another form of competition."

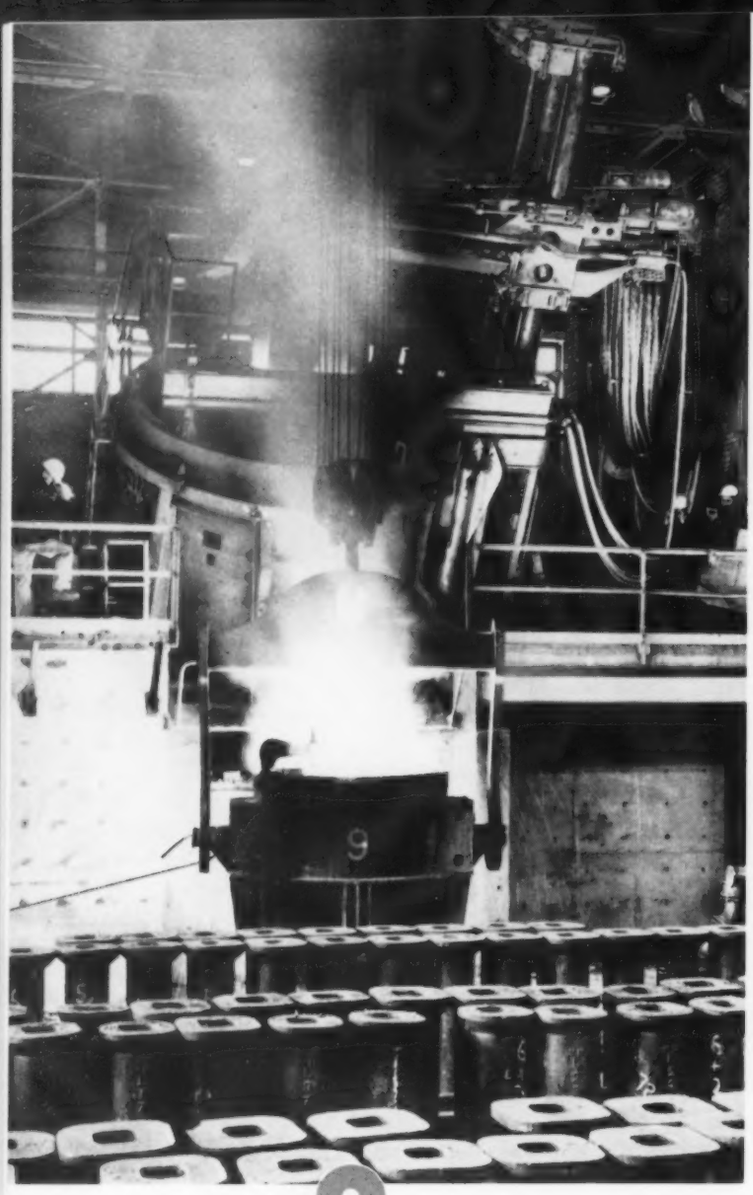
A series of statistics are presented indicating that certain industries, such as the electrical and clothing industries, claiming damage from imports, are really not badly hurt, since imports account for an extremely small fraction of the total consumption of these items in the United States. Thus imports can never take over the United States market, because "Brown Boveri and the other European producers of heavy mechanical and electrical power equipment are just that—European producers. Their first commitment obviously is to their home markets. Beyond that they have other flourishing and long-standing trade outlets in many parts of the world other than the U. S. . . . It is inconceivable and not worthy of serious consideration that these European producers would give up their traditional and profitable markets elsewhere in order to devote their entire production to an attack on the U. S. market."

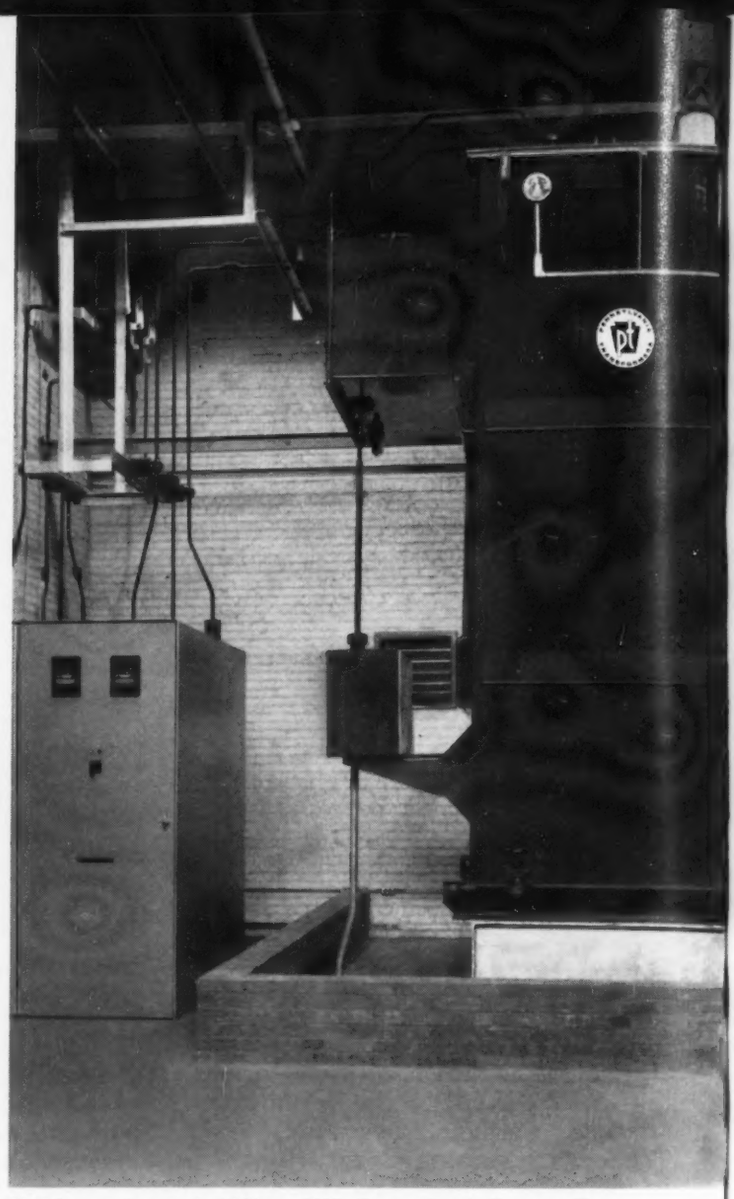
Further, the booklet goes on to say that imports are a direct benefit to the United States economy and the United States consumers since they are: (1) the best defense that this country has against creeping inflation, for continued import competition is said to be the best and perhaps the only sure way of retaining the benefits of free competition; (2) a means for introducing more rapid technological change in the domestic industry, which may become sluggish and unresponsive to the needs of a customer due to lack of strong competition which can be surely provided by the presence of imports; (3) a means of generating jobs and profits in the United States for hundreds of thousands of United States workers from long shoremen to retail salesmen are engaged in the handling and sale of imports; and (4) a means of increasing reciprocal trade in line with the objectives of the foreign policy of the United States.

The significant conclusion of the pamphlet is stated on the first page when the question is asked: What happens when you do not buy the best machine for the job simply because it is made outside the United States? We are told the result of such a decision is good neither for the company nor the United States because the savings from superior performance are lost, a healthy foreign trade is discouraged and United States manufacturers begin to rely on protection instead of competition.

This statement on imports, like so many others, deals with the problem either on a national or industry-wide basis, and thus is concerned with averages. It does not take into account the relatively large number of individual companies employing thousands of people who have been seriously affected. Many of the arguments presented have validity, but they afford small comfort to those firms who have lost a fairly large percentage of their business because their costs did not permit them to compete effectively with imported goods. It might be well for the theorist to say that a company which finds difficulty in competing should liquidate and employ its capital elsewhere to a greater advantage. However, this involves tremendous dislocation and hardship.

On the other hand it would be extreme to suggest that trade agreements and foreign policy should be based on the needs of a few companies, or for that matter a fairly large number of companies. However, they should not be disregarded. One of the ways in which we might express our regard for these companies is to modify the tax laws in such a way as to allow them adequate depreciation to modernize obsolete plant and equipment. Such action would go a long way toward making them competitive with foreign producers. ▲





7500-kva, water-cooled (Class OW), Pennsylvania Furnace Transformer with motor-operated tap changer, located in vault, supplies No. 3 arc furnace at Lemont Manufacturing Corporation. Pour is being made from the Lectromelt size "NOT" furnace, to fill the billet-size ingot molds.

for the 3RD time...

Steelmaker picks Pennsylvania electric arc furnace transformer

Lemont Manufacturing Corporation, the principal industry of Lemont, Illinois, recently increased by 50% its capacity to produce carbon steel for rolled structural shapes. The latest addition to this modern plant is a third 12-foot diameter Lectromelt Arc Furnace, supplied with power by a *third 7500-kva Pennsylvania Furnace Transformer*. Each of these furnace and transformer installations is capable of producing pours of 20 net tons at a rate of 7½ to 8 tons per hour—a ton every 7½ minutes.

In supplying power to melt this steel, the transformers do their job in a very unspectacular way. Externally, there is no hint of the internal "beating" they take. They must withstand high overloads and the repeated stresses caused by short circuits at the furnace electrodes. Yet, Lemont expects and *gets* dependable, trouble-free, day-in and day-out service from each of its three Pennsylvania Furnace Transformers.

Especially rugged in construction, Pennsylvania Furnace Transformers also have the inherent strength provided by a special winding design proven by 25 years of application. The design has been successfully applied to ratings as high as 40,000 kva and 82,000 amperes.

To take advantage of Pennsylvania's design experience and to obtain information on furnace transformer construction, contact Power Transformer Sales Dept., Pennsylvania Transformer Division, McGraw-Edison Company, Canonsburg, Pennsylvania.

PENNSYLVANIA FURNACE TRANSFORMERS

AISE Manual for Thermal Design of Regenerators

by J. W. HLINKA
Senior Research Engineer
F. S. PUHR
Research Engineer
and Dr. V. PASCHKIS
Professor, Mechanical Engineering
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Columbia University
New York, N. Y.

. . . . an extensive research project on checker design was financed by the AISE. The results follow. Because of the difficult mathematics involved, much of the effort was spent in developing a simple design procedure which is so set up that checker calculations can be done by a technician. Further work on effects of channeling and fouling might be desirable and result in even more accurate results for complete new installations. However, attached procedure can give very precise results for studies on modification of existing checkers. Procedure can also by programmed for computers . . . .

PART ONE— COMPUTING MANUAL FOR OPEN HEARTH REGENERATORS

THE production rate of open hearth furnaces is controlled in part by the flame temperature. For any given fuel, the maximum achievable temperature is a function of the temperature of the combustion air. A high temperature is very desirable from the viewpoint of economy, since the higher the air temperature, the less fuel is consumed per ton of steel. For these reasons a regenerator is a very important part of the open hearth system. Yet surprisingly few systematic studies have been published, particularly in American literature, on this subject. Considerations for open hearth regenerators apply almost equally to the regenerators for soaking pits and for glass furnaces. They are quite different from those for rotating regenerators of the Ljungstrom type, which are used increasingly for gas turbines and for which a fair amount of literature is available.

In this country the design of open hearth regenerators is largely based on extrapolation of experience. The legitimate question, in which direction to change design features in order to obtain desirable results, is left largely to the intuition of the designer.

The analytical solution for the regenerator problem is so complex as to make its use for engineering design purposes impractical. But by using a number of simplifications, a rational and rigid design procedure can be established. These simplifications are described in Part Two, to which reference is made for the theoretical development of the procedure and graphs described in this first part. A set of worksheets with specific step-by-step instructions is appended to the manual; the worksheets make it possible to assign the calculations involved in the thermal design of a

regenerator to a technician who should be able to complete a design in a reasonable length of time.

The procedures described in this manual are directly applicable to the determination of the time average behavior of a single flue in a regenerator. An ideal regenerator is simply made up of a number of such flues with the gas and air flows evenly distributed. Uneven distribution of gas and air flows, if the flow patterns are known, is handled by calculating each flue or group of flues separately and properly combining the results. The procedures hold for straight or chimney flues of rectangular cross section.

The method of calculation can be used for any value of constant gas and air entrance temperature. The purpose of the calculation is to determine the gas and air exit temperatures at the respective ends of the flues; the change in temperature between the end of the furnace and the top of the checker depends on factors not considered in this manual. The gas and air temperatures obtained are to be understood as the time mean temperature over the duration of one gas or air period respectively, and after the regenerator has reached "cyclic equilibrium."

Properties are taken as constant at the space-time mean temperature of the flue. The present manual is self-contained in that a design analysis or calculation can be made without recourse to any other source of information.

It should be noted that data on thermal conductivity and emissivity and, to a lesser degree, on specific heat and density of the flue materials differ greatly and care must be taken to introduce the best possible values. The data shown are taken from manufacturers' literature, but thermal property measurements are difficult to make and are not always reliable.

Convective heat transfer coefficients in brick flues are of major importance in regenerator design. There is relatively little information available and the selection of the coefficients in this manual is based on a paper by Boehm,[9] who studied this aspect in a specially designed brick flue; use of his equations in regenerator design has yielded satisfactory temperature predictions for actual regenerators.

NOMENCLATURE

Note: All units must be expressed in Btu, hours, lb, feet, atmospheres, and degrees F or R, as indicated. Do not use in. in the calculations.

A	=	Free cross-sectional area of a single flue, sq ft
A_t	=	Total cross section of a checker, sq ft
$B_1 - B_3$	=	Characteristic values for finding the length correction
c	=	Specific heat, Btu per lb, F
C	=	Correction factor for h_{gr}
C_T	=	Correction factor for temperature
D	=	Hydraulic diameter, ft
F_1, F_2, F_3	=	Auxiliary factors
F_R	=	Correction factor for roughness
$G_1 - G_4$	=	Characteristic values for finding the time correction
h	=	Heat transfer coefficient, Btu per sq ft, hr, F
k	=	Thermal conductivity, Btu per ft, hr, F
$K_1 - K_7$	=	Characteristic design factors
L	=	Length of a flue, ft
M	=	Volume flow rate of waste gas (expressed at 60 F) per unit total cross section, cu ft per hr, sq ft
Nu	=	Nusselt number
n	=	Number of flues in a checker
P	=	Perimeter of a single flue, ft
p_{CO_2}	=	Partial pressure of CO_2, atm
p_{H_2O}	=	Partial pressure of H_2O, atm
Pr	=	Prandtl number
p_t	=	Total pressure of the gas, atm
Q	=	Radiated heat flow, Btu per sq ft, hr
r	=	Air-to-gas ratio (volumes at 60 F)
R	=	Ratio of free cross section to total cross section of a checker
Re	=	Reynolds number
s	=	Gas layer thickness, ft
T	=	Temperature, F
$\bar{T}$	=	Absolute temperature ($\bar{T} = T + 460$), R
$U_{h_{gr}}$	=	Uncertainty in radiative heat transfer coefficient, per cent
U_0	=	over-all heat transfer coefficient, Btu per sq ft, hr, F
$U_{T_{ae}}$	=	uncertainty in air exit temperature, F
v	=	linear velocity (expressed at 60 F), ft per hr
w	=	mass flow rate, lb per hr
y	=	actual half-thickness of flue wall, ft
y_0	=	equivalent half-thickness of flue wall, ft

Greek letters

α	=	thermal diffusivity, sq ft per hr
ϵ	=	emissivity
θ	=	dimensionless temperature
ρ	=	density, lb per cu ft
τ	=	reversal period, hr
μ	=	viscosity, lb per ft, hr

Subscripts

a	=	air
c	=	convection
e	=	exit
g	=	gas
i	=	inlet
m	=	mean
r	=	radiation
w	=	wall
∞	=	infinite layer thickness
CO_2	=	carbon dioxide
H_2O	=	water vapor

Superscripts

$'$	=	length correction included
$''$	=	combined length and time correction included
$\circ$	=	with zero partial pressure

STATEMENT OF PROBLEM

Problem—The problem which may be solved by use of this manual is the determination of the time mean gas and air exit temperatures over the duration of one period and after the regenerator has reached "cyclic equilibrium," that is, the temperatures in two consecutive cycles are the same. A lower limit of the mean

brick temperature at the hot end of the regenerator, taken over an entire cycle, is also determined. The temperatures in a regenerator change during the length of a reversal period, but because of difficulties of presentation only time mean temperatures are given.

Remarks—As stated in the preface, the manual may be used to compute the time mean exit temperature of gas and air from a regenerator or from a single flue. While all the graphs refer to a single flue, the total regenerator can be computed by multiplying the mass flow rates of gas and air through a single flue by the total number of flues. In so proceeding it is, of course, necessary to select for the single flue the average values for mass rate of flow. Because of channeling, the value of mass rates may be vastly different in different parts of the regenerator. If the channeling is understood, it is desirable not to work with average values, but instead to compute the air and gas exit temperatures for the several flues, using for each flue or, perhaps, for each group of flues its individual mass rate of flow. This is preferable, because the performance is not proportional to velocity and working with an average heat transfer coefficient found for an average velocity would introduce additional errors.

Examples and the worksheets are found later in this article. In the description of the computational procedure given later, the worksheet applicable to each step is indicated in parentheses.

Assumptions—It is assumed that heat flow to and from the ends of the flues and heat losses to the surroundings may be neglected.

Constant properties and heat transfer coefficients (i.e., independent of space, time or temperature) which should be based on the space-time mean temperature of the fluid are assumed. The space-time mean indicates a temperature integrated with respect to time and the length of the flue; charts showing the space-time mean temperatures are included in the manual. It is assumed that the mass of the gas or air contained in the flue at any instant is negligible compared to the mass of brick. This assumption was proved correct by computer computations wherein the effect was unobservable in a case selected to yield a maximum effect. All curves are drawn under the assumption that gas and air entrance temperatures are constant during the reversal period.

SELECTION OF PROPERTIES

Thermal conductivity, specific heat, density and emissivity for some materials used in open hearth checkers are tabulated in Tables I, II, III and IV respectively; properties of gases are shown in Tables V and VI.

These values were obtained from sources indicated within the tables. Determination of thermal properties, particularly of conductivity and emissivity is difficult to make and not always reliable. Also, in the case of refractory materials, manufacturing techniques have an influence on the values.

The effect of inaccurate thermal properties may, for a particular design, be negligible; this can be checked by computing a regenerator twice, once assuming minimum and another time maximum values for a particular property.

CALCULATION OF HEAT TRANSFER COEFFICIENTS

The heat transfer coefficient (h) is measured in Btu per sq ft, hr, F. It indicates the rate of heat exchange between the refractory and gas or air, referred to unit area and unit temperature difference between solid and fluid.

The heat transfer coefficient during the air period and that during the gas period are usually not equal; during the air period heat transfer from the brick occurs by convection only, during the gas period the gas transfers heat to the brick by convection (h_{gc}) and by radiation (h_{gr}). The two modes are additive, that is $h_g = (h_{gc} + h_{gr})$; the method of computing the convective coefficient is the same for air and gas.

Properties of gas and air change markedly with temperature. Inasmuch as the space-time mean temperatures upon which the properties are based are not known originally, a trial and error method must be followed. Values are assumed initially and verified upon completion of the regenerator calculation. The computational procedure will be presented in three parts:

1. Convective heat transfer coefficient.
2. Radiative heat transfer coefficient.
3. Combined heat transfer coefficient.

Convective heat transfer coefficient—The convective coefficient for air or gas is a function of: surface roughness (see Figure 1), velocity and flue size (see Figures 3a and 3b) and temperature (see Figure 2).

Worksheet 1—Estimate the expected surface roughness, selecting one of the types from Figure 1 as representative. Read the roughness correction factor (F_R) and note if Figure 3a or 3b is to be used.

Worksheet 2—Make an estimate or guess of the space-time mean gas, air and wall temperatures. In the absence of better information, these can be taken as the arithmetic means of the expected cold and hot end temperatures.

Worksheet 3—Compute the linear velocity (ft per hr) of gas and air, both taken at 60 F. The nature of this calculation depends on the given data; if R, the ratio of free cross section to total cross section of a checker; r, the volume air to gas ratio; and M, the volume flow rate of waste gas per unit total cross section of the regenerator, are given, the linear velocities for gas and air are determined as follows:

$$v_g = \frac{M}{R} \tag{1}$$

$$v_a = v_g r = \frac{Mr}{R} \tag{2}$$

Compute the hydraulic diameter of the flue from Equation 3:

$$D = \frac{4A}{P} \tag{3}$$

Determine F_1 using Figure 3, which is presented in two parts. Figure 3a holds for flues of roughness type A–E, Figure 3b holds for flues of roughness type F–I. Read the velocity on the abscissa; for the appropriate flue size (marked on the curves) read on the ordinate scale the value of F_1.

Find the temperature correction factor (C_T) from Figure 2.

Compute h_c from Equation 4:

$$h_c = F_i F_R C_T \quad (4)$$

RADIATIVE HEAT TRANSFER COEFFICIENT

The value depends (Worksheet 4) on the emissivity of both brick and gas, the latter being dependent on the partial pressures of the radiating components of the gas (mainly CO_2 and H_2O) on the total pressure, on flue size and on mean temperatures. For many cases the simplified procedure presented hereafter is sufficient. Ranges of applicability of this procedure are:

Mean gas temperature	between	500 and 2600 F
Mean wall temperature	between	500 and 2600 F
Hydraulic diameter	between	0.25 and 0.85 ft
Wall emissivity	between	0.75 and 0.85
Gas composition	H_2O between	6 and 20 per cent
	CO_2 between	6 and 15 per cent
Total pressure	1 atm	

Using the space-time mean gas and wall temperatures assumed on Worksheet 2, turn to Figure 6. Read T_{gm} on the abscissa axis and proceed vertically to the line of constant hydraulic diameter (D) for the value computed from Equation 3; thence proceed horizontally and read Q_{gm} on the ordinate. Similarly use the same graph for T_{wm} and read Q_{wm}.

Obtain a correction factor (C) from Figure 5. Read the percentage of H_2O on the abscissa axis and the percentage of CO_2 noted on the curves; the correction factors are plotted as ordinates. Determine h_{gr} from Equation 5:

$$h_{gr} = C\left[\frac{Q_{gm} - Q_{wm}}{T_{gm} - T_{wm}}\right] \quad (5)$$

If conditions are outside the range of applicability listed above, or if the error due to the simplified procedure is too large, see Equation 31, the general procedure given in the Appendix must be used.

COMBINED HEAT TRANSFER COEFFICIENT

The total coefficient (Worksheet 4) for the gas cycle (h_g) is the sum of the individual values determined for convection and radiation.

$$h_g = h_{gc} + h_{gr} \quad (6)$$

Take h_{gr} from above if the simplified procedure was used, otherwise from Equation A-7 in the Appendix.

Since during the air cycle, heat is exchanged only by convection:

$$h_a = h_{ac} \quad (7)$$

DETERMINATION OF GAS AND AIR EXIT TEMPERATURES

The exit temperature determination can be divided into several parts. As first step in the calculation a number of characteristic factors are computed, using the temperatures previously assumed. The general procedure of calculation is based on that for a counter-flow heat exchanger, an apparatus in which heat storage is not part of the exchange procedure. Two corrections are introduced in order to utilize the heat exchanger equations for regenerators: one to account for the conduction in the flue wall parallel to the direction of gas flow and the other to account for the periodic passage of air and gas through the flue.

Graphs and procedures for the computation of temperatures are presented. The space-time mean gas, air and wall temperatures and the gas and air exit temperatures are determined and if necessary the calculation is repeated with new assumptions.

Characteristic factors—Based on thermal properties of gas, air and brick, on geometry and on reversal period, seven characteristic design factors $K_1 - K_7$ can be defined as shown below (Equations 9 to 15). The specific heats of gas and air at their space-time mean temperatures are first determined (Worksheet 5). Densities of gas and air are taken at 60 F (Worksheet 1). The thermal properties of the flue wall are to be taken at the space-time mean wall temperature (Worksheets 6 and 7). The geometry of the system may be described by the perimeter of the flue opening, the length of the flue and the effective wall half-thickness. The latter is not equal to the half-thickness of the brick, because of corner effects, see Figure 4, but is defined by Equation 8 (Worksheet 6):

$$y_0 = \frac{A_t(1 - R)}{Pn} = \frac{\text{total brick cross-sectional area}}{\text{sum of flue perimeters}} \quad (8)$$

The seven characteristic factors are (Worksheets 6 and 7):

$$K_1 = \frac{L}{y_0} = \frac{\text{length of flue}}{\text{effective wall half-thickness}} \quad (9)$$

$$K_2 = \frac{1}{1 + (h_a/h_g)} = \frac{1}{1 + (K_5/K_6)} \quad (10)$$

$$K_3 = \frac{k_w LP}{Ay_0(\rho cv)_g} \quad (11)$$

$$K_4 = \frac{k_w LP}{Ay_0(\rho cv)_a} \quad (12)$$

$$K_5 = \frac{k_g}{h_g y_0} \quad (13)$$

$$K_6 = \frac{k_w}{h_a y_0} \quad (14)$$

$$K_7 = \frac{\alpha\tau}{y_0^2} \quad (15)$$

Length correction—In the simple and conventional method of computing counter flow heat exchangers it is assumed that there is no heat conduction in the wall parallel to the flow of gas (Worksheet 8). In regenerators this assumption is sometimes not permissible. To account for this longitudinal conduction, the sum of the characteristic factors (K_5 and K_6) is to be replaced by the sum ($K_5' + K_6'$). The step-by-step procedure for computing ($K_5' + K_6'$) is as follows:

1. Determine K_4/K_3; if K_4/K_3 does not equal 1, follow steps two to four; if $K_4/K_3 = 1$, a simple equation, shown in five, is used.

2. Determine the values of B_2 and B_3 from Equations 16 and 17 respectively.

$$B_2 = \frac{1 - (K_4/K_3)}{[(K_5 + K_6)/K_3] + (K_4/K_1^2)} \quad (16)$$

$$B_3 = \frac{(K_4K_5/K_3) - K_6}{K_1^2[1 - (K_4/K_3)]} \quad (17)$$

3. With the values for B_2 and B_3, determine B_1 from Figure 7; this figure obviates the need for computing B_1 from Equation 18.

$$B_1 = \frac{1 - \sqrt{1 - 4B_2^2B_3}}{2B_2B_3} \quad (18)$$

4. Having found B_1, one finds $(K_5' + K_6')$ from Equation 19.

$$(K_5' + K_6') = \frac{K_3}{B_1}\left(1 - \frac{K_4}{K_3}\right) \quad (19)$$

5. If $K_4/K_3 = 1$, use Equation 20 directly for the determination of $(K_5' + K_6')$.

$$(K_5' + K_6') = K_5 + K_6 + \left(\frac{K_3}{K_1}\right)^2 \quad (20)$$

Time correction—The "time correction" (Worksheet 9) makes the equations for a "heat exchanger with longitudinal conduction" applicable to a regenerator.

1. The correction consists of determining a value of $(K_5'' + K_6'')$, replacing $(K_5' + K_6')$, see length correction. The procedure involves some auxiliary factors, G_1 to G_4.
2. Determine G_1 from Figure 8, in which G_1 is plotted against $1/K_7$.
3. Using G_1, compute G_2 and G_3 from Equations 21 and 22 respectively:

$$G_2 = \frac{2K_7}{(K_5' + K_6') + G_1} \quad (21)$$

$$G_3 = \frac{4}{[(1/K_3) + (1/K_4)][(K_5' + K_6') + G_1]} \quad (22)$$

4. Determine G_4 from Figure 9 or 10, the latter being an enlargement of the left upper corner of the former. In both figures G_4 is plotted vs G_2 for various values of G_3. Now compute $(K_5'' + K_6'')$ from Equation 23:

$$(K_5'' + K_6'') = \frac{(K_5' + K_6') + G_1}{G_4} \quad (23)$$

Determination of temperature ratios—Temperatures are put into ratio form (Worksheet 9) Equations 24a to 26a respectively:

$$\theta_g = \frac{T_g - T_{ai}}{T_{gi} - T_{ai}} \quad (24a)$$

$$T_g = \theta_g(T_{gi} - T_{ai}) + T_{ai} \quad (24b)$$

$$\theta_a = \frac{T_a - T_{ai}}{T_{gi} - T_{ai}} \quad (25a)$$

$$T_a = \theta_a(T_{gi} - T_{ai}) + T_{ai} \quad (25b)$$

$$\theta_w = \frac{T_w - T_{ai}}{T_{gi} - T_{ai}} \quad (26a)$$

$$T_w = \theta_w(T_{gi} - T_{ai}) + T_{ai} \quad (26b)$$

1. Compute the value $(K_5'' + K_6'')/K_3$.
2. In Figure 11 read $(K_5'' + K_6'')/K_3$ on the abscissa; determine θ_{gm} by using the appropriate curve K_4/K_3.
3. Proceed in the same manner to determine θ_{am} from Figure 12.
4. Proceed in the same manner to determine θ_{ge} from Figure 13. For the sake of readability Figure 13 is presented in four individual plots, Figures 13a to 13d, each having a different range on the abscissa scale.
5. Compute θ_{wm} from Equation 27. This equation is to be used for estimating purposes only and does not give exactly the mean wall temperature because it disregards longitudinal heat conduction in the bricks.

$$\theta_{wm} = K_2(\theta_{gm} - \theta_{am}) + \theta_{am} \quad (27)$$

Determination of temperatures—Compute T_{gm} from Equation 24b, T_{am} from Equation 25b, T_{wm} from Equation 26b and T_{ge} from Equation 24b (Worksheet 10).

Compute the air exit temperature ratio from Equation 28.

$$\theta_{ae} = \frac{K_4}{K_3}(1 - \theta_{ge}) \quad (28)$$

Determine the air exit temperature (T_{ae}) from Equation 25b.

Compute the approximate brick temperature at the hot end of the regenerator. The time mean value over an entire cycle can be estimated from Equation 29:

$$T_{w(maximum)} = K_2(T_{gi} - T_{ae}) + T_{ae} \quad (29)$$

The maximum brick temperature occurs at the end of the gas period. Determination of the maximum is complicated and not presented here. However, two limits can be stated: the maximum brick temperature is lower than the gas inlet temperature and higher than the temperature obtained from Equation 29. For a more accurate estimate of the lower limit, replace K_2 in Equation 29 by a corresponding expression evaluated at the gas and air temperatures at the hot end of the regenerator. A higher estimate always results, thus narrowing the gap between lower and upper limits but the rather tedious procedure of recalculating h_a and h_g for the higher temperatures is required. It is recommended that this be done only for those cases where $T_{w(maximum)}$ is of considerable importance. The procedure in the worksheets uses the K_2 previously calculated.

Since the h values depend on temperatures not known but only assumed at the start of the calculation, the whole procedure should be repeated until two successive calculations yield final air temperatures differing by less than the allowable error.

Uncertainty in air exit temperature—Even after successfully completing the calculations, there still remains an uncertainty due to use of the simplified procedure for determination of the radiative component of the heat transfer coefficient. The maximum uncertainty in the air exit temperature must be ascertained and if it is larger than acceptable, general procedure shown in the Appendix must be used. The value of h_{gr} from the Appendix is then introduced into Equation 6, and the entire ensuing procedure repeated. Fortunately, this will rarely be necessary.

The maximum uncertainty in air exit temperature

is found as follows (Worksheet 11):

1. Compute factor F_2 from Equation 30:

$$F_2 = \frac{1 - (K_4/K_3)}{[(K_5'' + K_6'')/K_3]} \quad (30)$$

2. Use Figure 14, reading F_2 on the abscissa axis, the appropriate curve for $(K_5'' + K_6'')/K_3$ and, finding F_3 on the ordinate axis.

3. Determine $U_{h_{gr}}$ from Figure 15; it is the maximum per cent uncertainty in h_{gr} when the latter is determined according to this procedure.

In Figure 15 the percentage of CO_2 in the gas is plotted on the abscissa, the H_2O content is noted on the curves, and $U_{h_{gr}}$ is read on the ordinate scale.

4. Now the maximum uncertainty in air exit temperature in degrees can be computed from Equation 31:

$$U_{T_{ae}} = \left(\frac{U_{h_{gr}}}{100}\right)\left(\frac{F_3}{G_4}\right)\left(\frac{K_5}{K_3}\right)\left(\frac{1}{1 + (h_{ge}/h_{gr})}\right)(T_{gi} - T_{ai}) \quad (31)$$

EXAMPLES AND WORKSHEETS

In this section the use of the manual and worksheets is illustrated by showing one computation in detail and the results of a number of others.

The designer may prefer to use the equations and charts directly. The worksheets serve the purpose of reducing the calculation procedure to a convenient, easily followed routine.

Results of a number of calculations follow and a detailed solution comes next.

Results of illustrative computations—Conditions (in part) for a base case and the calculated results are given. Items not listed may be found on the key to example one. The effects of changing several conditions, one at a time, on air and gas exit temperatures are then shown:

1. *Base case*—

Conditions:

Volume flow rate of waste gas at 60 F, M	2500 cu ft per hr, sq ft
Air to gas volume ratio, r	0.89
Flue size	7.5 x 7.5 in.
Flue wall thickness	3 in.
Flue wall material	Fireclay
Flue length, L	20 ft
Reversal period, τ	15 min
Gas inlet temperature, T_{gi}	2600 F
Air inlet temperature, T_{ai}	100 F

Results:

Air exit temperature	1925 F
Gas exit temperature	1300 F

2. If the flue length is decreased from 20 to 8 ft

Air exit temperature	1300 F (625 F lower)
Gas exit temperature	1780 F (480 F higher)

3. If the flue size is increased from 7.5 x 7.5 to 9 x 9 in.

Air exit temperature	1880 F (45 F lower)
Gas exit temperature	1330 F (30 F higher)

Note that the increase in flue size increases the ratio of free to total cross section thus decreasing gas and air velocities in the flues. This effect is important. If gas and air velocities in the flues are not changed, the calculated air exit temperature is 1815 F, 110 F lower than the base case.

4. If the flue wall thickness is decreased from 3 to 2 in.

Air exit temperature	2040 F (115 F higher)
Gas exit temperature	1195 F (105 F lower)

Again the decrease in flue velocities is important. If these are not changed, the calculated air exit temperature is 1930 F, practically the same as in the base case.

5. If the reversal period is decreased from 15 to 5 min.

Air exit temperature	1955 F (30 F higher)
Gas exit temperature	1270 F (30 F lower)

The calculation shows that some increase in air temperature can be obtained by shortening the reversal period.

6. If the flue material is changed from fireclay to silicon carbide.

Air exit temperature	1980 F (55 F higher)
Gas exit temperature	1255 F (45 F lower)

Under conditions of the base case, a large change in brick conductivity has a relatively small effect.

7. If the gas flow rate is increased from 2500 to 3500.

Air exit temperature	1735 F (190 F lower)
Gas exit temperature	1430 F (130 F higher)

If the base case is assumed to be the design condition, it can be seen that "overloading" the regenerator by 40 per cent decreases the air exit temperature by 190 F.

8. If the distribution of gas and air flows are uneven. In this case the regenerator is divided into five equal groups of flues with flow distributions as given in the table. Note that the total flow rate is the same as in the base case.

Group	*Gas velocity, per cent of average*	*Gas flow rate, per cent of total*	*Air velocity, per cent of average*	*Air flow rate, per cent of total*	*Air exit temperature, F*	*Gas exit temperature, F*
A	175	35	35	7	2600	2230
B	135	27	60	12	2410	1845
C	95	19	95	19	1960	1270
D	60	12	135	27	1340	615
E	35	7	175	35	740	225
Average	100	100	100	100	1495	1650

Note that in averaging the gas and air exit temperatures for the individual groups of flues, proper allowance for variation of specific heats with temperature should be made. The average air temperature for this distribution pattern is 1495 F, 430 F lower than for the base case with uniform distribution of flows.

COMPUTATION DATA

GRAPHIC DATA CURVES

DATA TABLES — WORK SHEETS

(Editors Note: All material needed to solve checker problems have been grouped for the convenience of the designer.)

A set of worksheets and a key giving the complete computation of the base case follows.

The design engineer will normally fill in Worksheet 1, the basic data and assumptions. The individual performing the computation then proceeds step by step through the worksheets, following the instructions given there. One can best become familiar with the procedure by actually making the calculations of the base case, following the manual and the worksheets and using the key to check the results at the completion of each sheet.

It is assumed that a calculating machine will be used for the various arithmetical operations involved. All such results in the key are given to four figures even though not justified by the over-all accuracy of the procedure. The reason for carrying four figures is the advantage of a uniform instruction for rounding off results.

Key to Example One

Line	Sheet 1	Sheet 2		Sheet 3		Sheet 4	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
1	2500	1950	2000	2500	...	14	...
2	0.89	1998	2003	0.89	...	13	...
3	*	1230	1100	0.391	...	1950	2000
4	0.0766	1095	1095	2.5	...	1800	1820
5	0.0764	1800	1820	0.51	...	0.6256	...
6	2600	1815	1825	1.0	...	5220	5520
7	100	1275	1300	3b	...	4370	4480
8	0.25	1922	1923	1950	2000	850	1040
9	$7\frac{1}{2}$x$7\frac{1}{2}$	2463	2467	1230	1100	150	180
10	3			4902	...	5.667	5.778
11	20			1.564	...	0.975	...
12	0.391			0.6256	...	5.525	5.634
13	1148			1.92	...	2.179	2.191
14	1500			1.135	1.141	7.704	7.825
15	2.5			2.179	2.191	1.948	1.912
16	0.51			2.179	2.191		
17	Fireclay			4363	...		
18	120			1.88	...		
19	0.8			1.036	1.017		
20	H			1.948	1.912		
21	1.0			1.948	1.912		
22	3b						
23							
24							
25							
26							
27							
28							
29							

Key to Example One (Continued)

Line	Sheet 5		Sheet 6		Sheet 7		Sheet 8		Sheet 9		Sheet 10		Sheet 11
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
1	1950	2000	0.0766	...	0.0764	...	133.3	...	0.7981	0.8039	2600	...	14
2	1230	1100	20	...	0.25	...	5.621	5.615	5.621	5.615	100	...	13
3	14	...	0.391	...	0.391	...	7.731	7.875	7.731	7.875	0.7981	0.8039	2600
4	13	...	1148	...	Fireclay	...	0.7035	0.6952	0.2518	0.2527	1.375	1.402	100
5	70	...	1500	...	120	...	2.782	2.845	1.375	1.402	0.759	0.761	2.191
6	3	...	2.5	...	1800	1820	3.486	3.540	3.490	3.543	0.398	0.398	5.634
7	...	...	0.51	...	4363	...	1.375	1.402	3.971	3.957	0.470	0.480	5.615
8	...	...	Fireclay	...	7.704	7.825	...	...	0.37	0.37	0.6861	0.6898	0.6952
9	0.308	0.309	1800	1820	1.948	1.912	−0.375	−0.402	3.860	3.913	2500	...	−0.402
10	0.595	0.600	4902	...	0.2690	0.2650	0.6202	0.6305	0.5036	0.5054	1898	1903	1.0
11	0.285	0.286	7.704	7.825	0.813	0.816	17,770	17,770	0.1305	0.1292	1998	2003	0.6969
12	0.285	0.286	1.948	1.912	0.1500	...	0.0004350	0.0004432	0.1779	0.1781	995.0	995.0	−0.5768
13	...	...	0.3285	0.3300	40.65	40.80	0.6206	0.6309	0.1293	0.1270	1095	1095	0.376
14	...	...	0.813	0.816	0.299	0.299	−0.6043	−0.6372	0.3072	0.3051	1715	1725	2.5
15	4.312	4.326	0.49	...	0.02055	0.02025	0.9673	0.9747	1.186	1.194	1815	1825	0.1238
16	7.735	7.800	562.5	...	89.66	88.35	−1.815	−1.870	3.373	3.350	1175	1200	0.3889
17	19.95	20.02	3750	...	35.06	34.54	4.840	4.652	1.0	1.0	1275	1300	1.389
18	0.855	0.858	0.1500	...	5.259	5.181	0.0002723	0.0002618	3.860	3.913	0.530	0.520	0.7199
19	...	...	133.3	...	7.731	7.875	−0.604	−0.637	0.6867	0.6969	0.7288	0.7290	2500
20	...	...	0.2528	0.2443	5.420	5.440	−2.108	−2.257	0.759	0.761	1822	1823	0.9400
21	32.85	33.00	1.253	1.244	0.7035	0.6952	3.490	3.543	0.398	0.398	1922	1923	0.1164
22	0.3285	0.3300	0.7981	0.8039	2.782	2.845	...	...	0.470	0.480	678.0	677.0	0.08380
23	0.2690	0.2650	0.02516	0.02528	35.88	35.88	...	...	0.361	0.363	541.1	544.2	209.5
24			123.3	123.9	0.02266	0.02274	...	...	0.2881	0.2918	2463	2467	209.5
25			48.21	48.44	0.02250	...	...	...	0.6861	0.6898			2.095
26			7.232	7.266	0.005665	0.005685	...	...					
27			16.26	16.32	0.2518	0.2527							
28			40.65	40.80									
29			5.621	5.615									

* 14 per cent CO_2, 13 per cent H_2O, 3 per cent O_2, 70 per cent N_2.

Type		Flow direction	Correction factor, F_R	Use with fig. 3
A	Smooth		1.0	a
B	Serrated	$9\frac{7}{16}$"	1.16	a
C	Serrated	$9\frac{7}{16}$"	1.16	a
D	Serrated	$9\frac{15}{16}$"	1.25	a
E	Serrated	$4\frac{3}{4}$"	1.25	a
F	Rounded	$4\frac{3}{4}$"	0.93	b
G	Serrated	$4\frac{3}{4}$"	0.99	b
H	Rounded	$4\frac{3}{4}$"	1.0	b
I	Serrated	$4\frac{3}{4}$"	1.05	b

Figure 1 — Types of roughness and roughness correction factors to be used in design calculations.

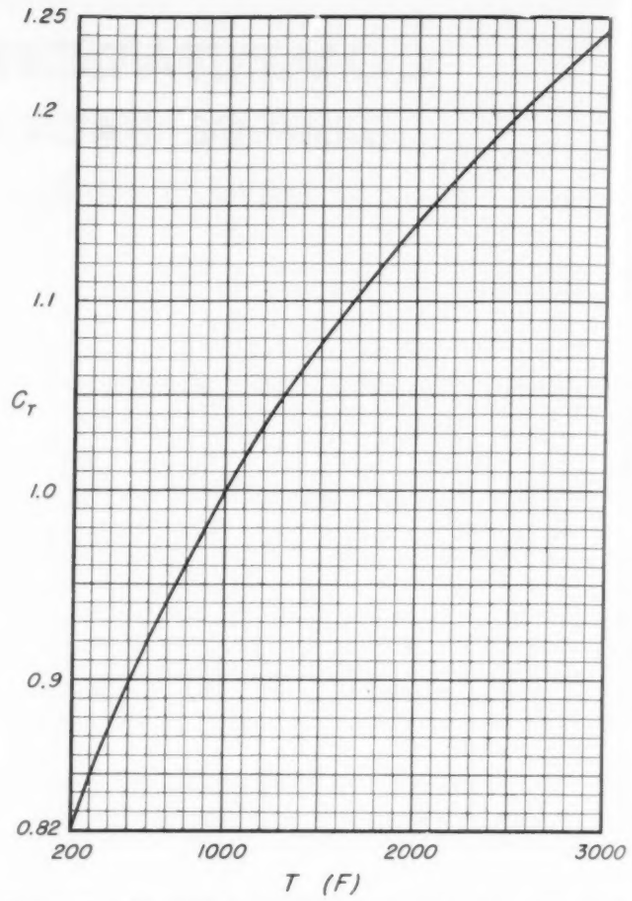
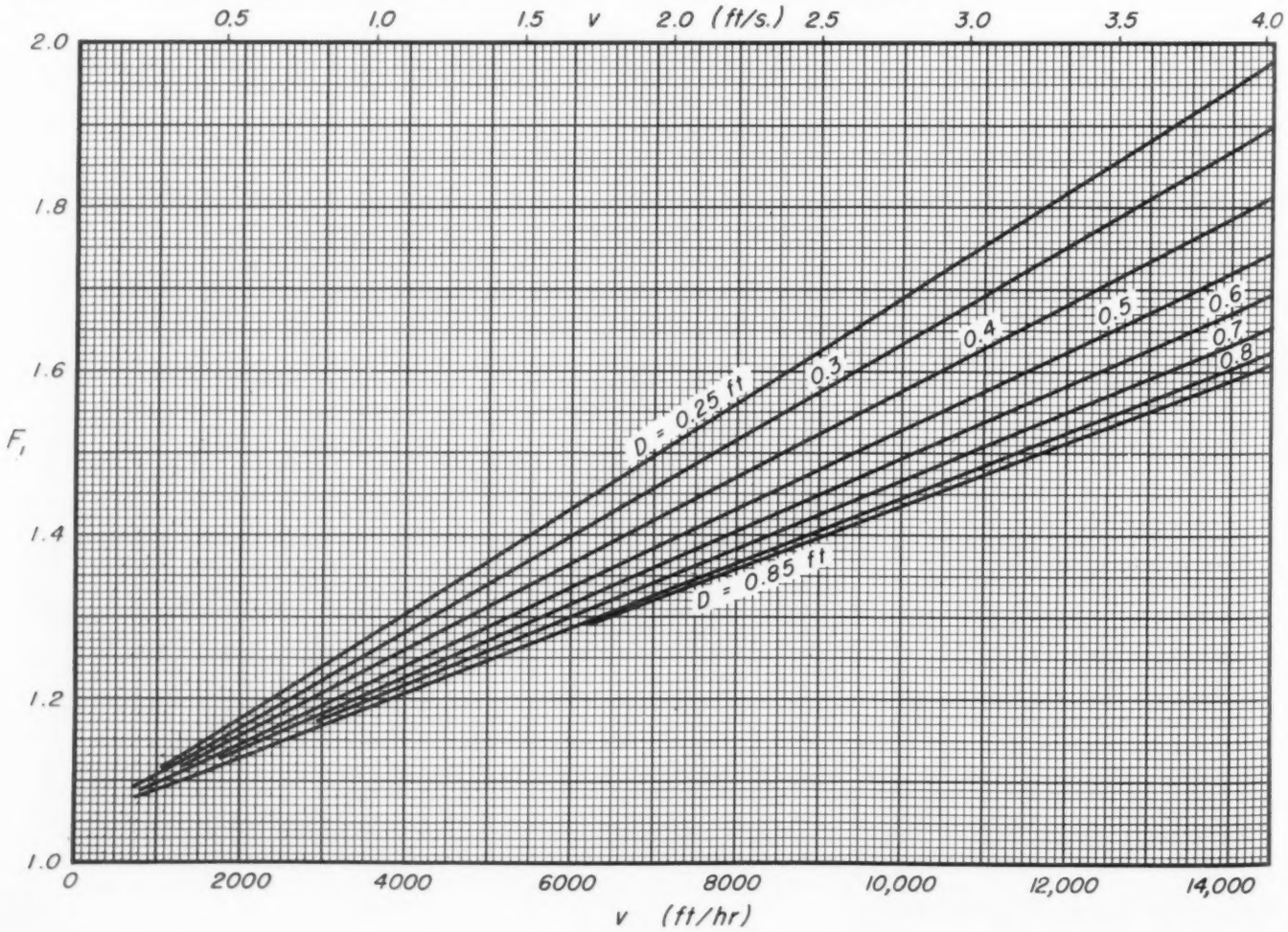


Figure 2 — Temperature correction factor for convective heat transfer coefficient.

Figure 3a — Convective heat transfer coefficients at 1000 F are given for roughness types A–E.



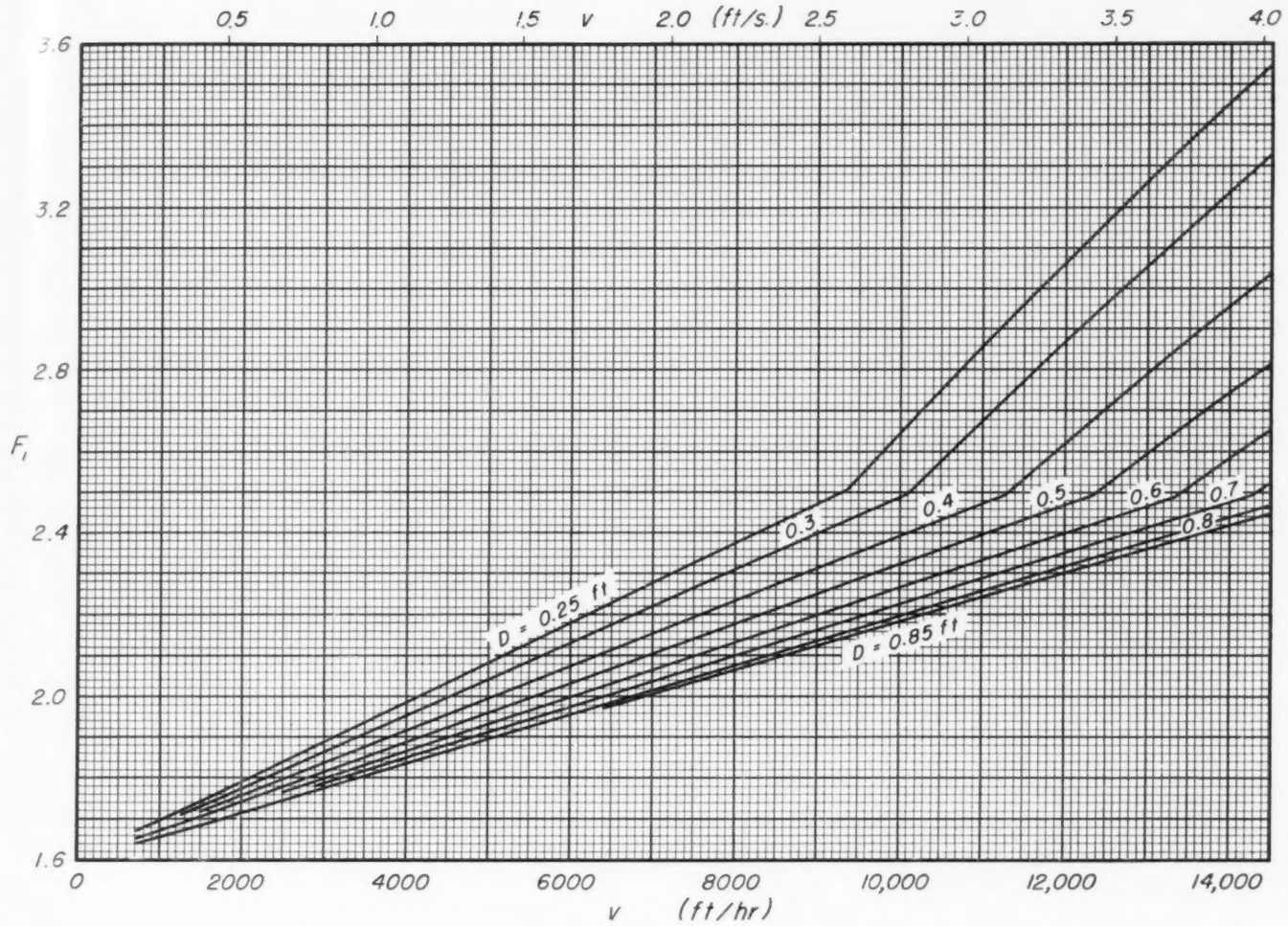
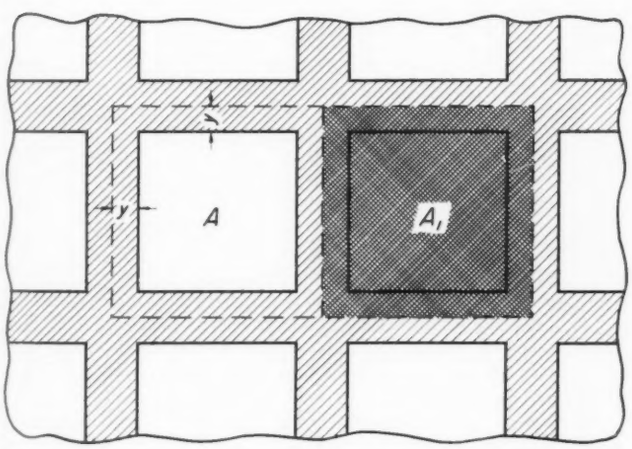


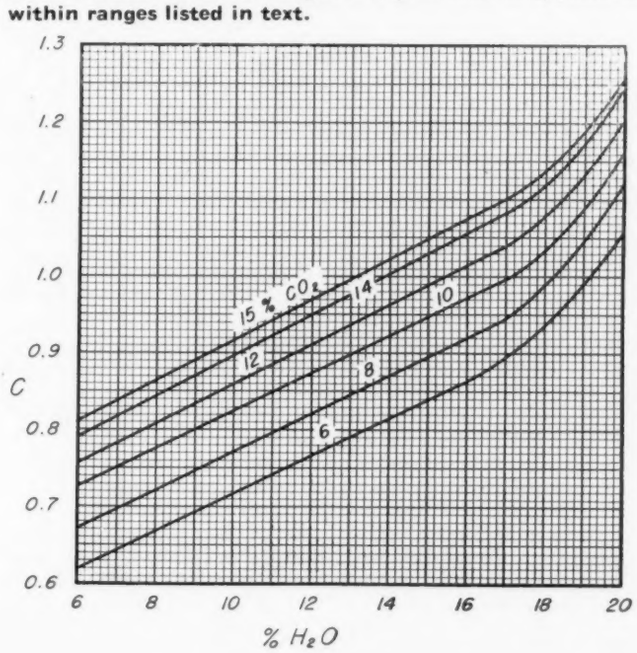
Figure 3b — Convective heat transfer coefficients at 1000 F are given for roughness types F–I.



$$R = \frac{A}{A_1}$$

Figure 4 — Cross section of flues.

Figure 5 — Correction factor for radiative coefficient of heat transfer for different gas compositions is applicable within ranges listed in text.



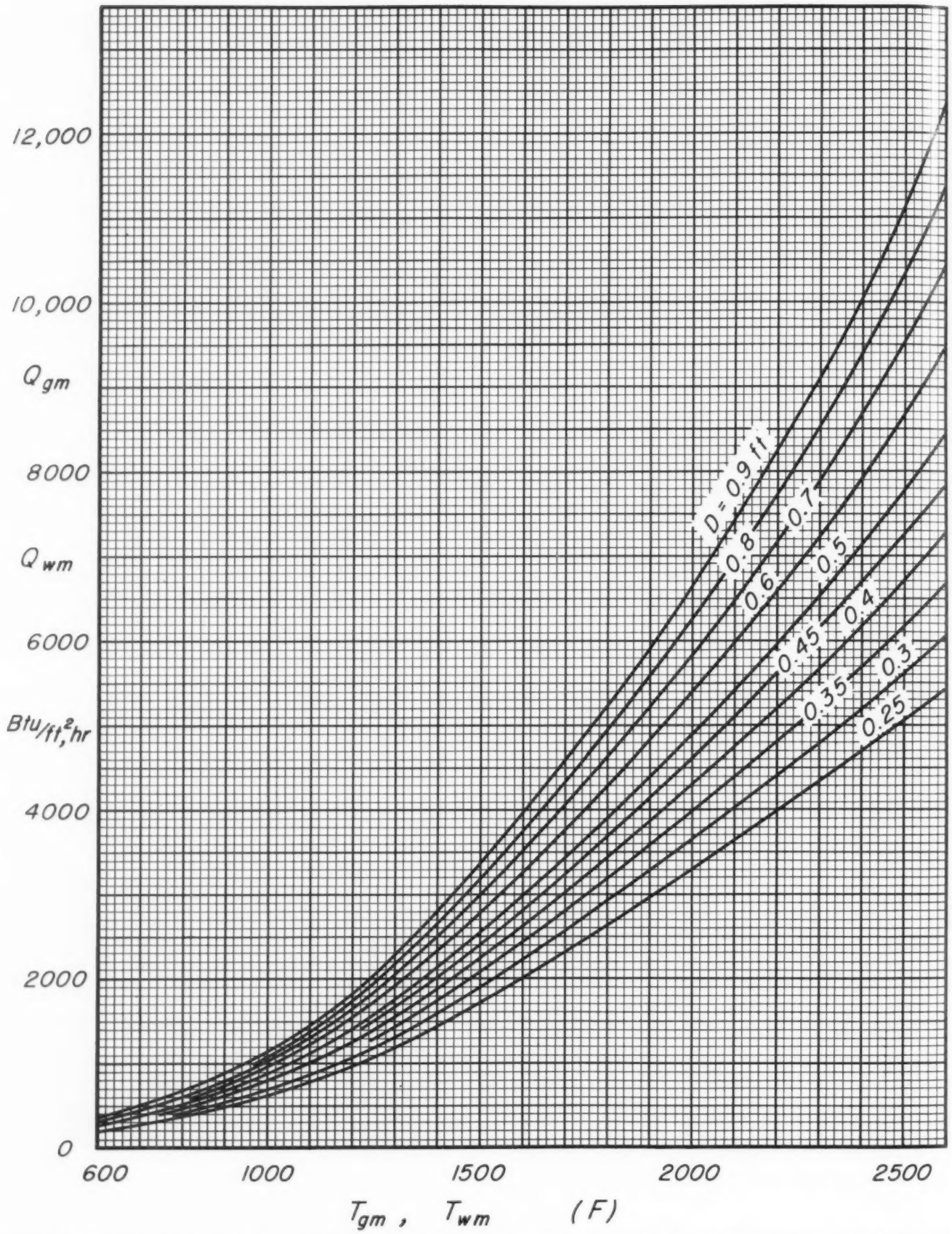


Figure 6 — Radiated heat flow vs temperature data hold for a gas comprising 14 per cent CO_2, 13 per cent H_2O, balance diathermic; total gas pressure 1 atm, wall emissivity 0.8.

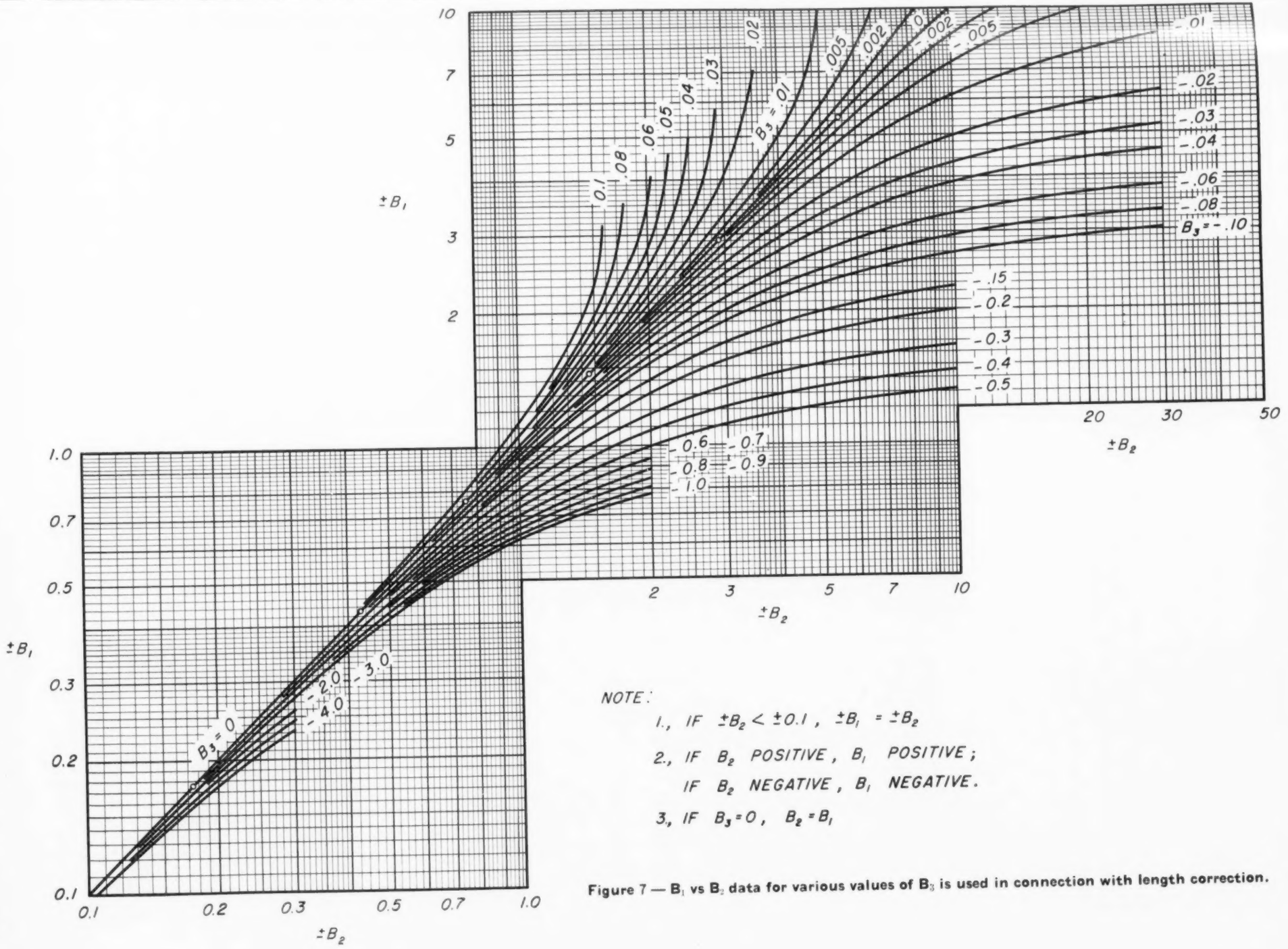
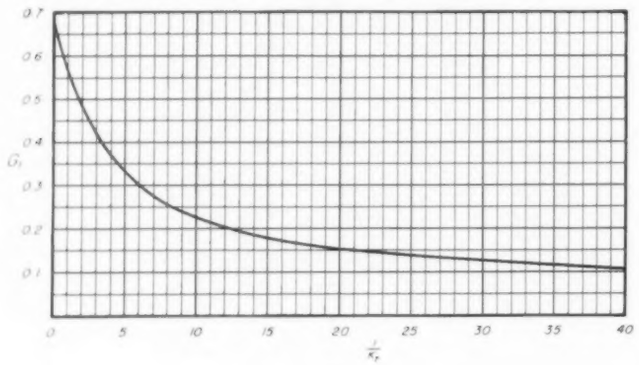


Figure 7 — B_1 vs B_2 data for various values of B_3 is used in connection with length correction.

Figure 8 — G_1 vs $1/K_7$ data is used in connection with time correction. Data from Hausen. From VDI-Waermeatlas, by kind permission of VDI Verlag, GmbH.



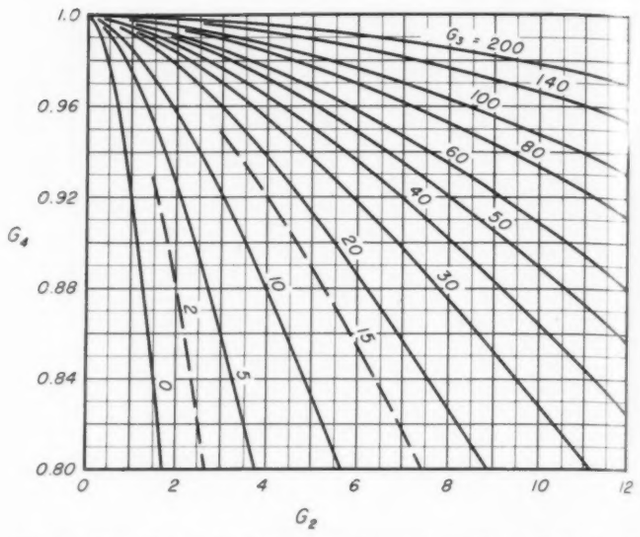


Figure 10 — G_4 vs G_2 data is enlarged version of part of Figure 9.

Figure 9 — G_4 vs G_2 data is used in connection with time correction. Data from Hausen. From VDI-Waermeatlas, by kind permission of VDI Verlag, GmbH.

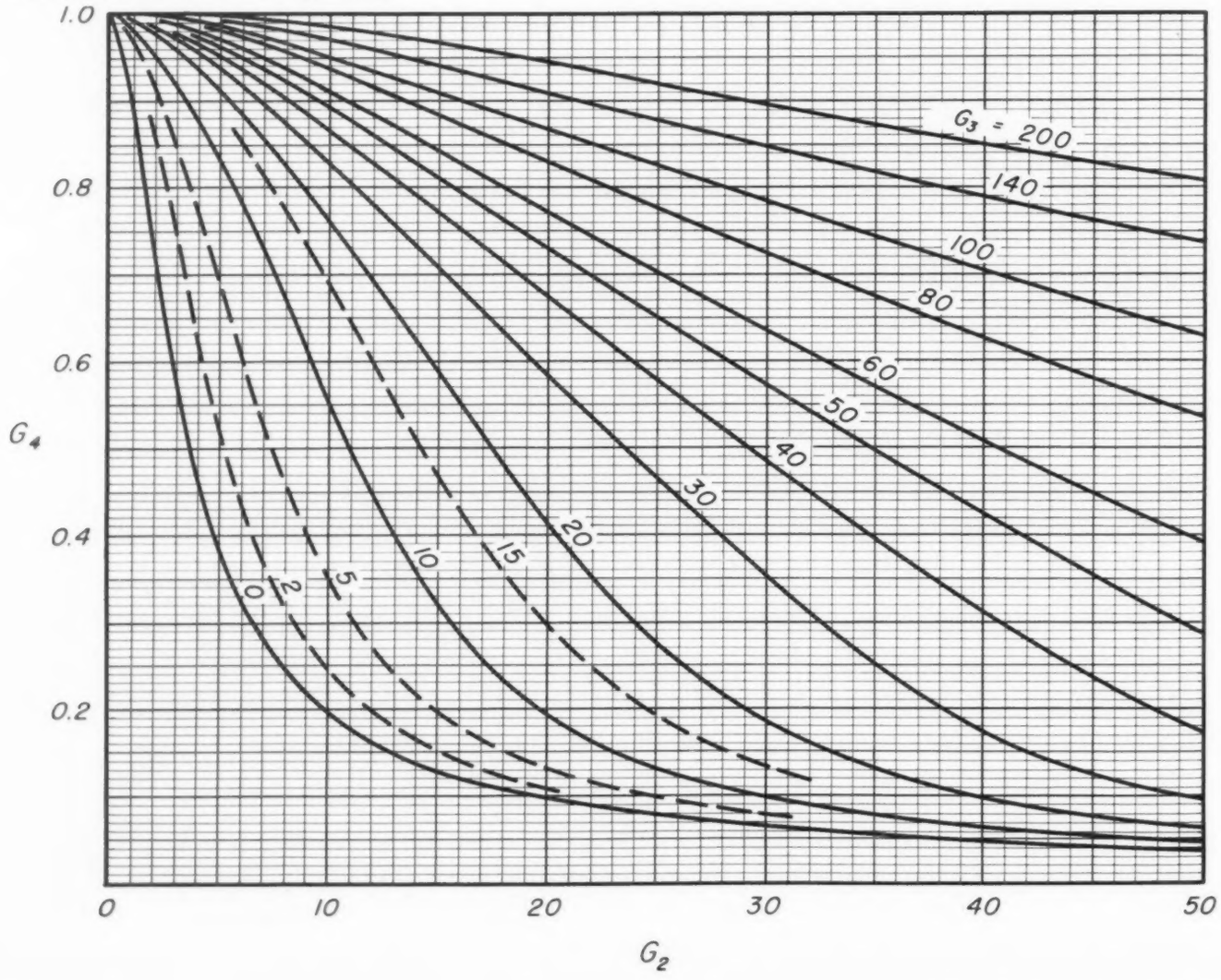


Figure 11 — θ_{gm} dimensionless space-time mean gas temperature vs $[(K_5'' + K_6'')/K_3]$.

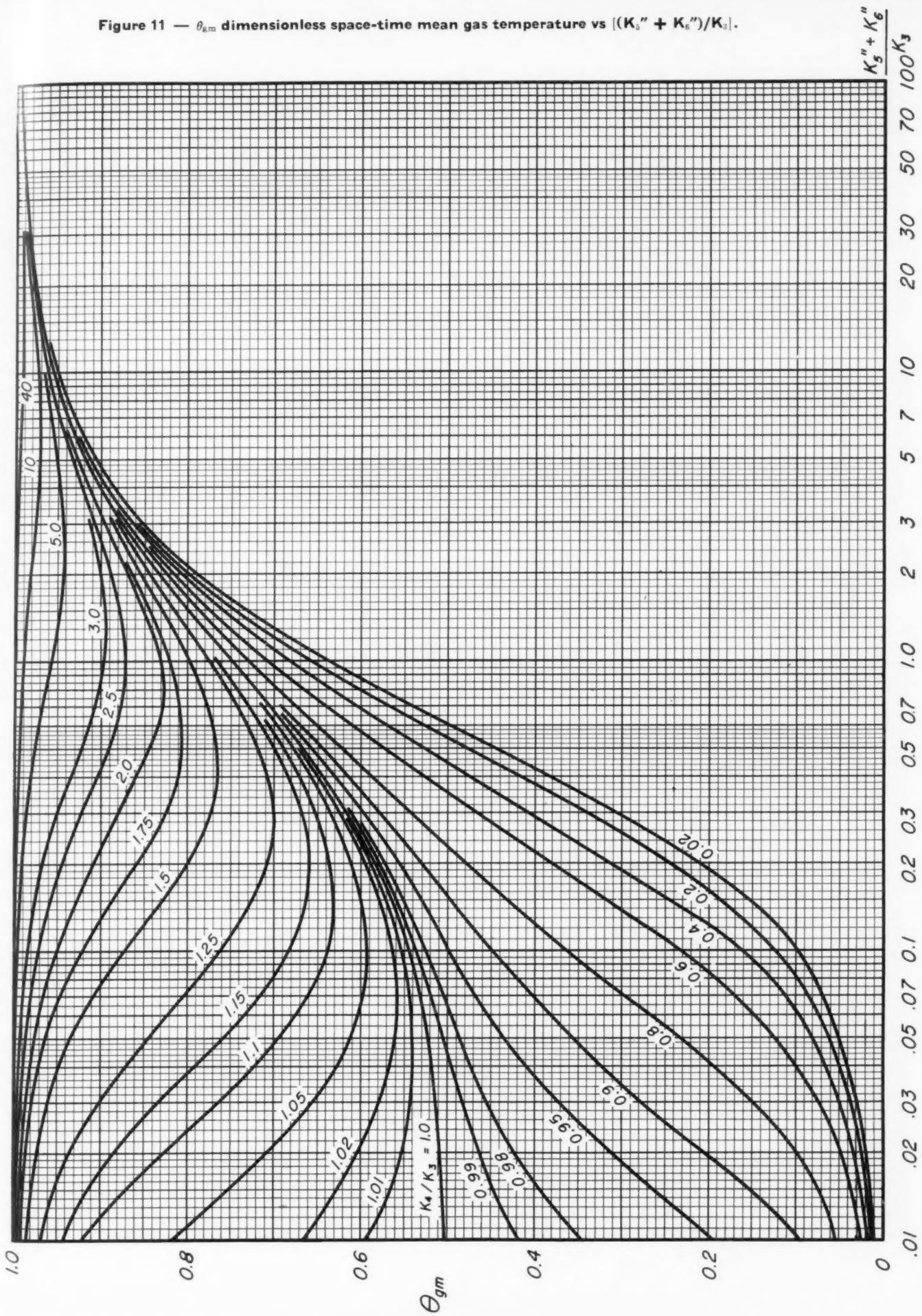


Figure 12 — θ_{am} dimensionless space-time mean air temperature vs $[(K_5'' + K_6'')/K_3]$.

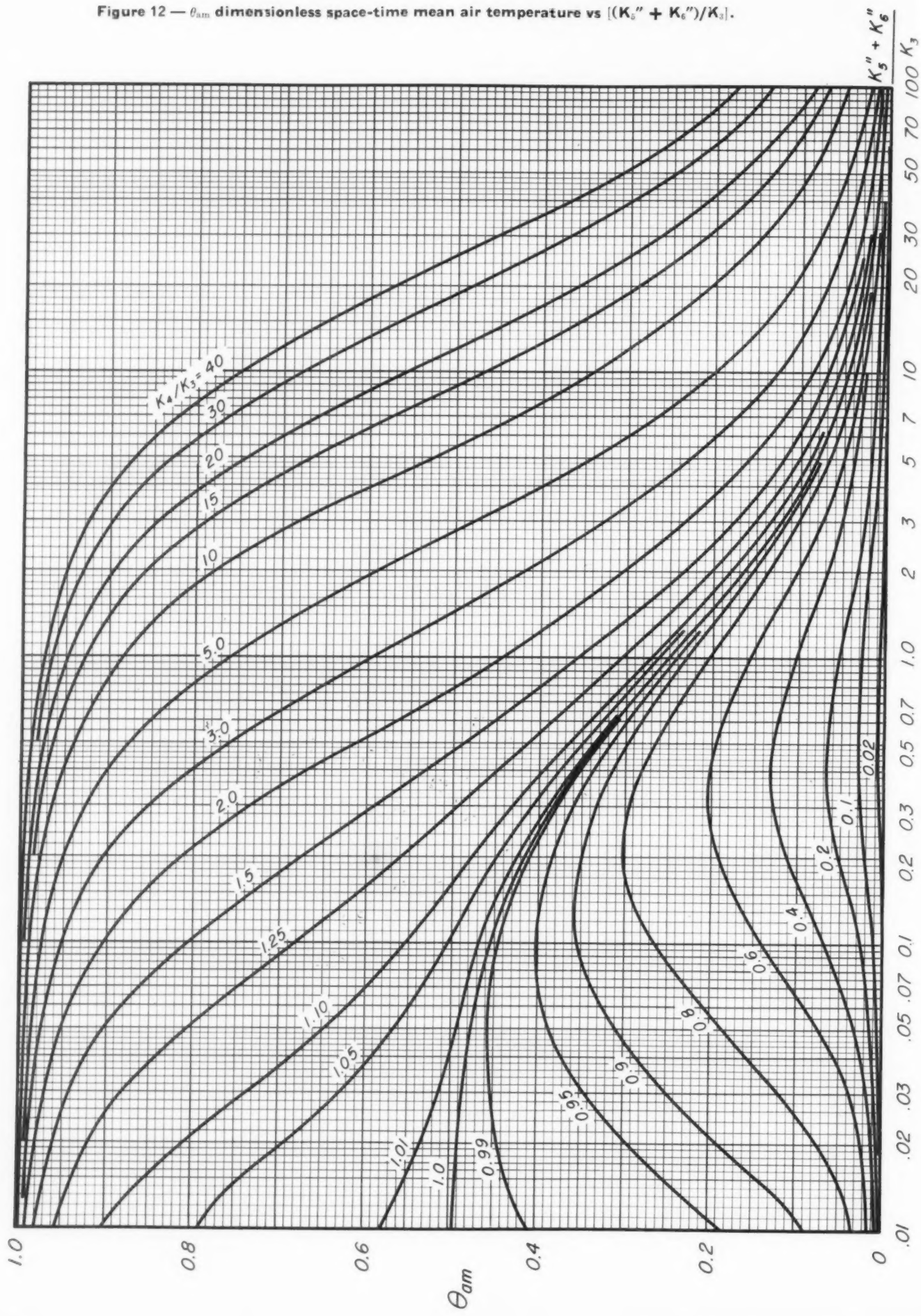
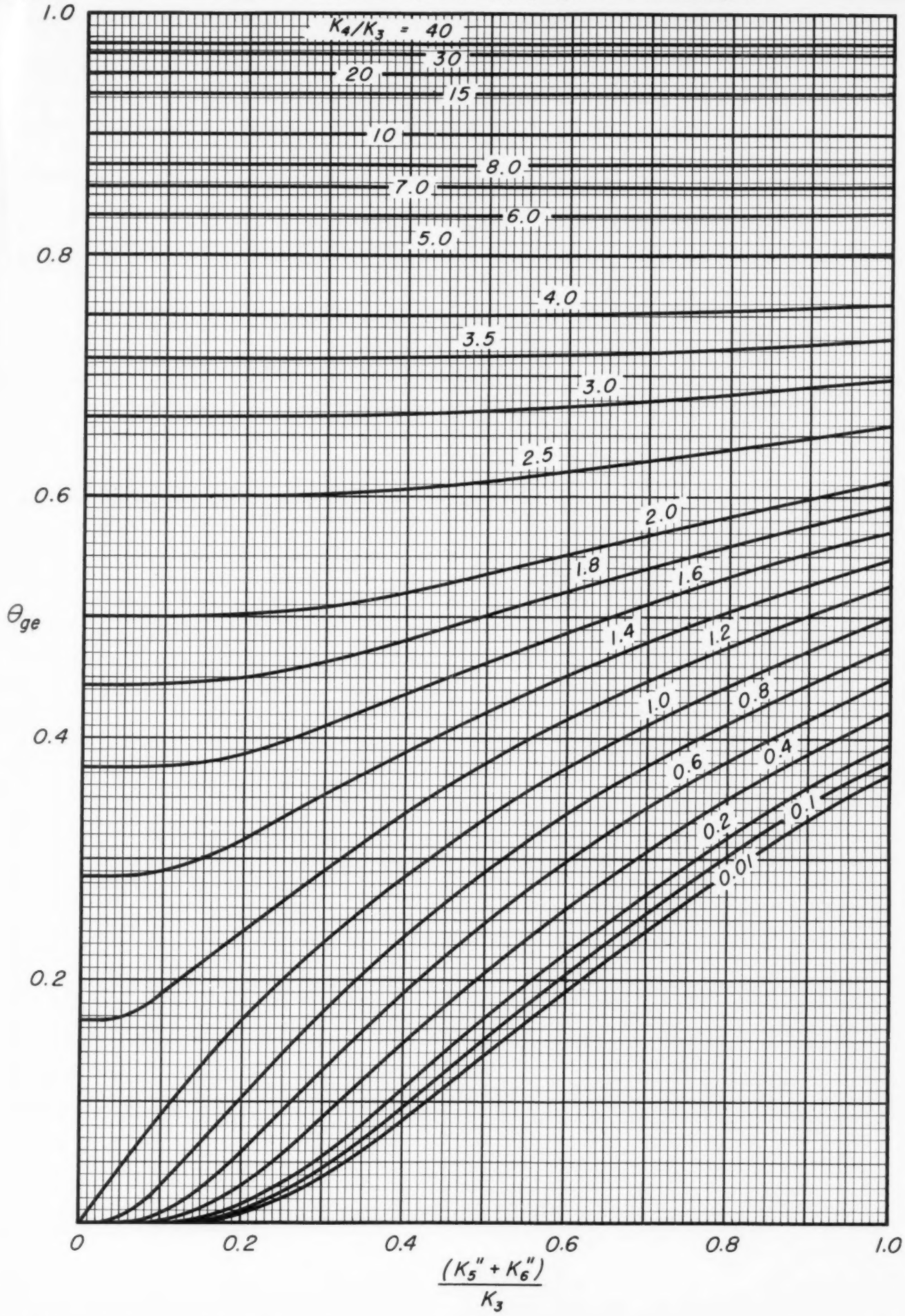


Figure 13a — θ_{ge} dimensionless gas exit temperature vs $[(K_5'' + K_6'')/K_3]$ is given for abscissa range 0–1.



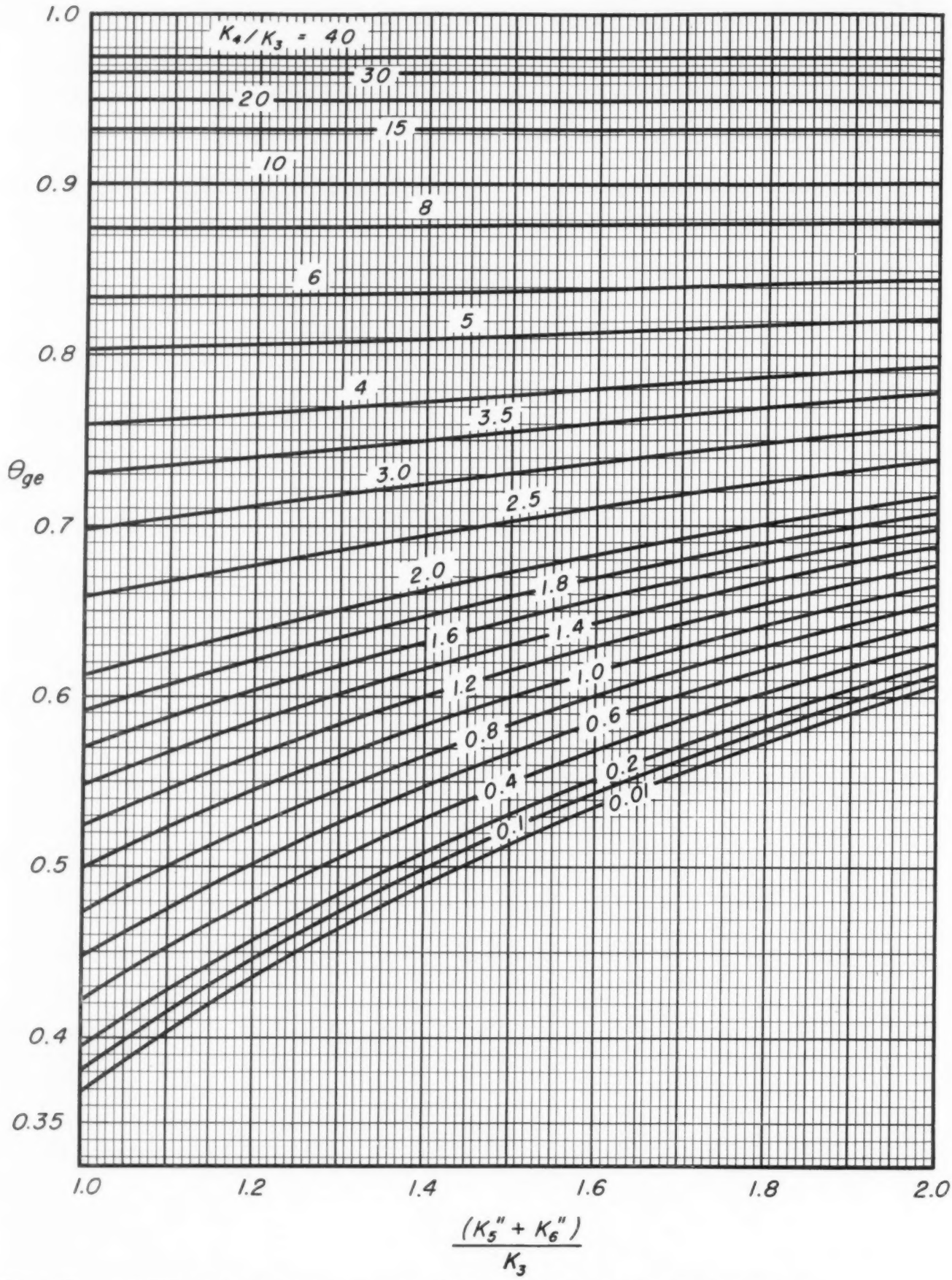


Figure 13b — θ_{ge} dimensionless gas exit temperature vs $[(K_5'' + K_6'')/K_3]$ is given for abscissa range 1–2.

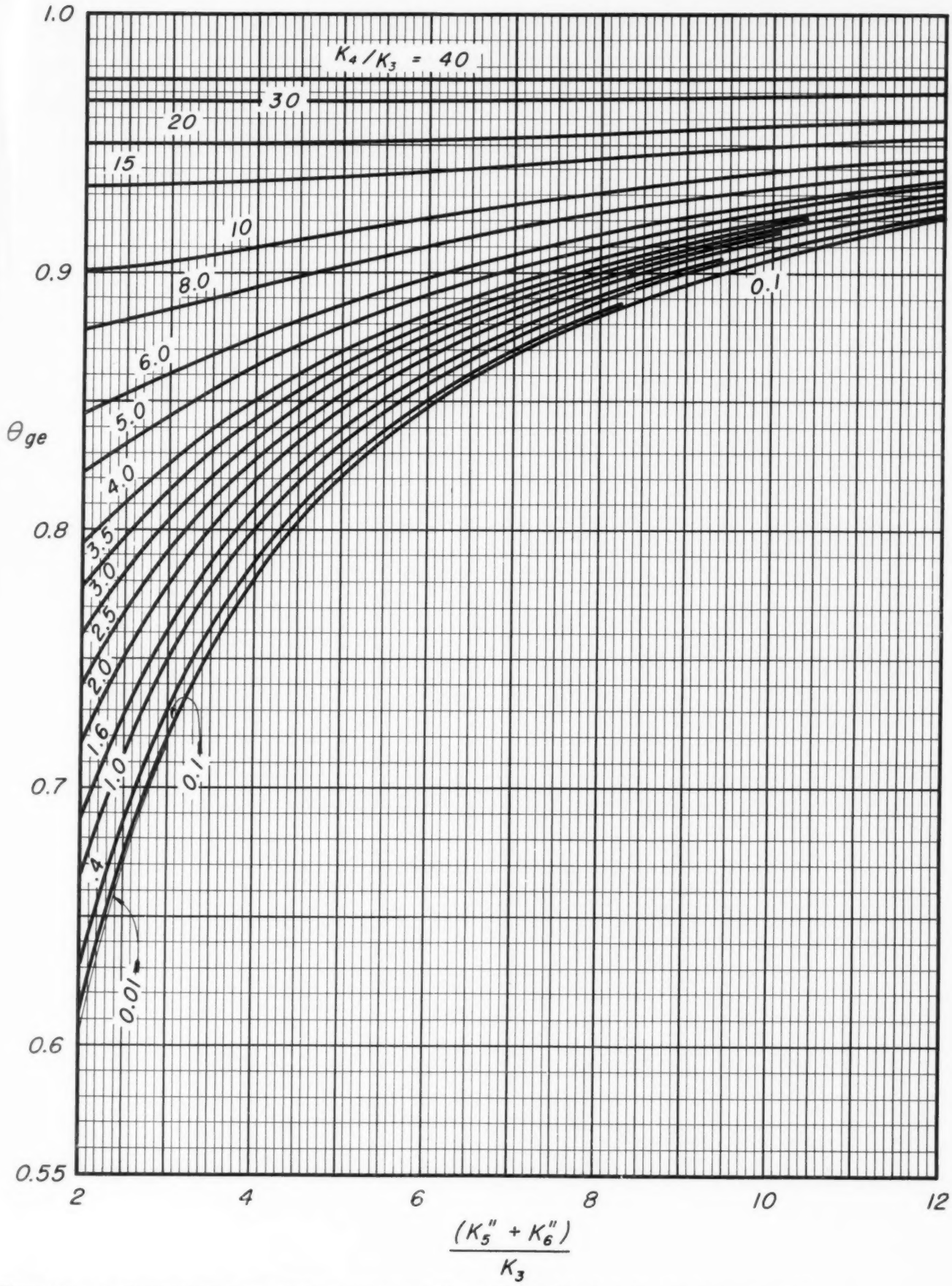


Figure 13c — θ_{ge} dimensionless gas exit temperature vs $[(K_5'' + K_6'')/K_3]$ is given for abscissa range 2–12.

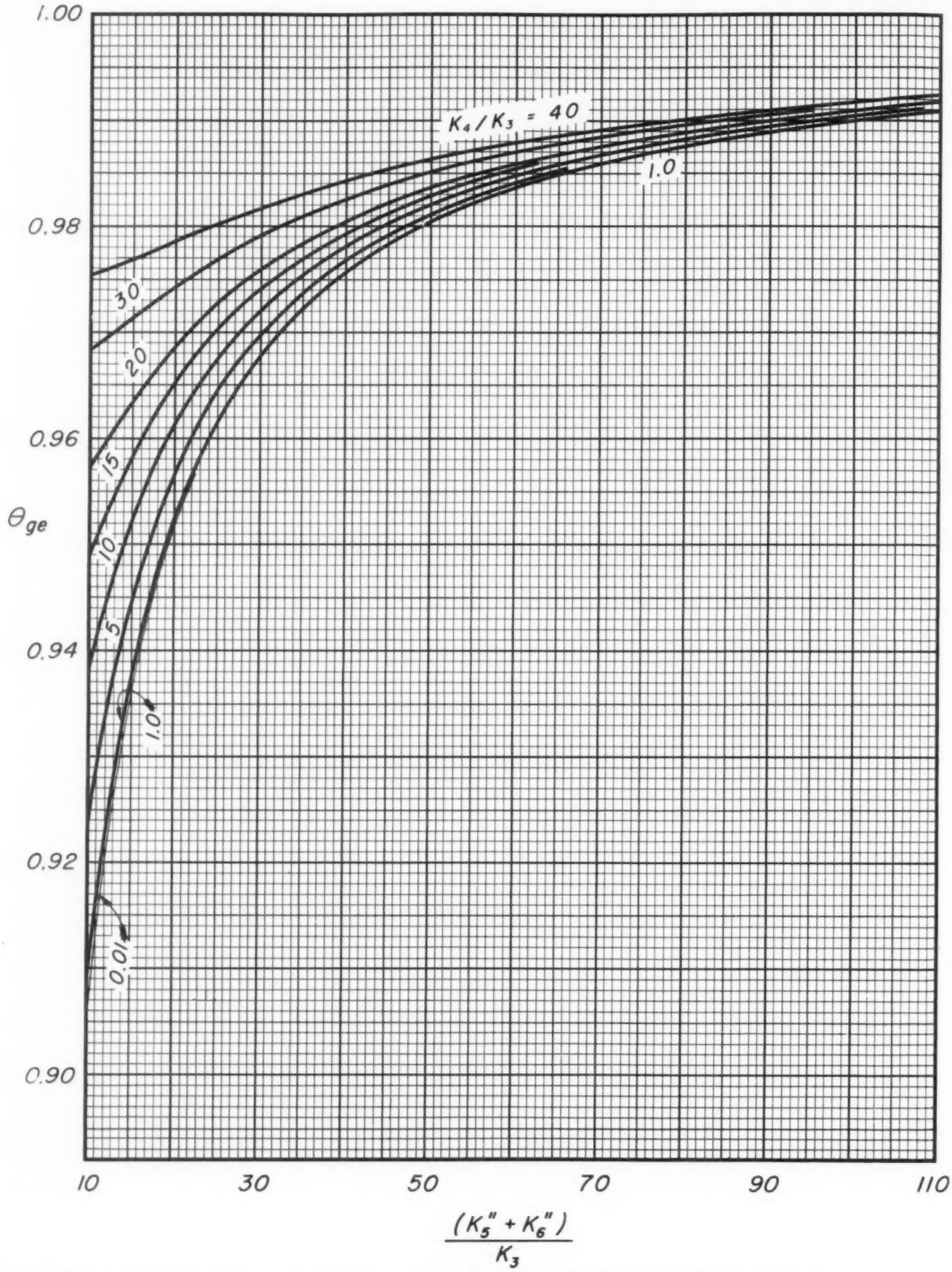


Figure 13d — θ_{ge} dimensionless gas exit temperature vs $[(K_5'' + K_6'')/K_3]$ is given for abscissa range 10–110.

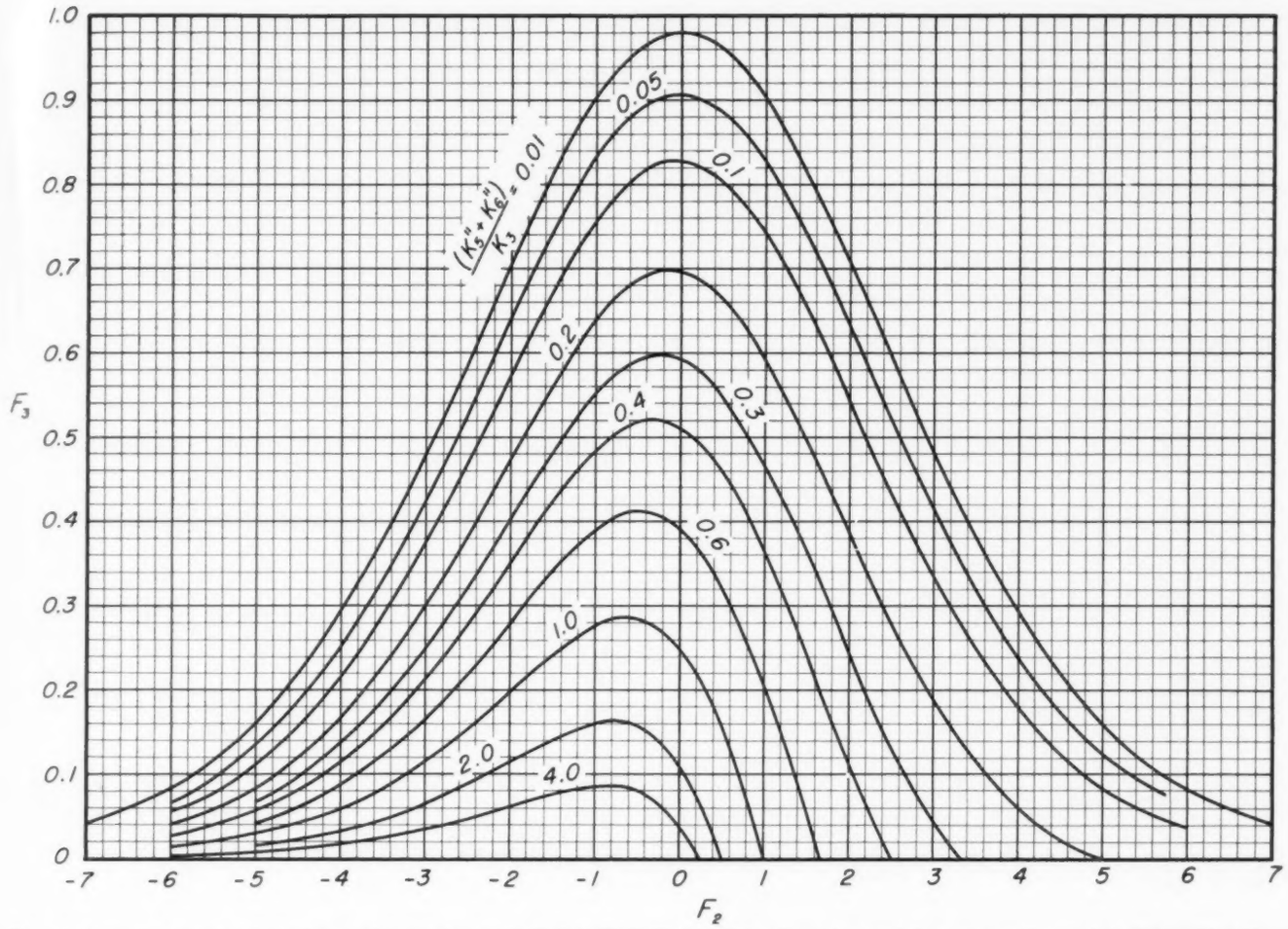


Figure 14 — F_3 vs F_2 is given for various values of $(K_5'' + K_6'')/K_3$. This chart is used in connection with determination of the uncertainty in air exit temperature.

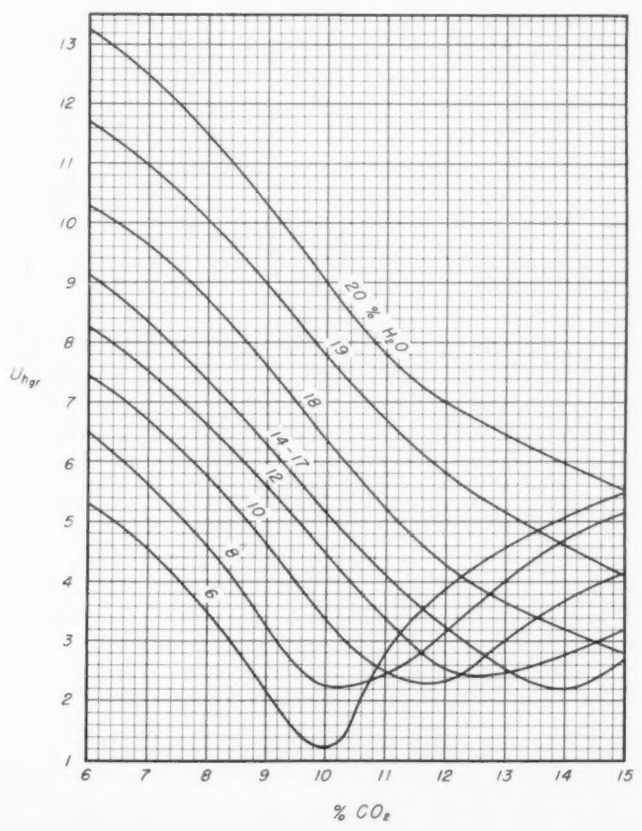


Figure 15 — Percentage uncertainty in radiative heat transfer coefficient for various gas compositions is given.

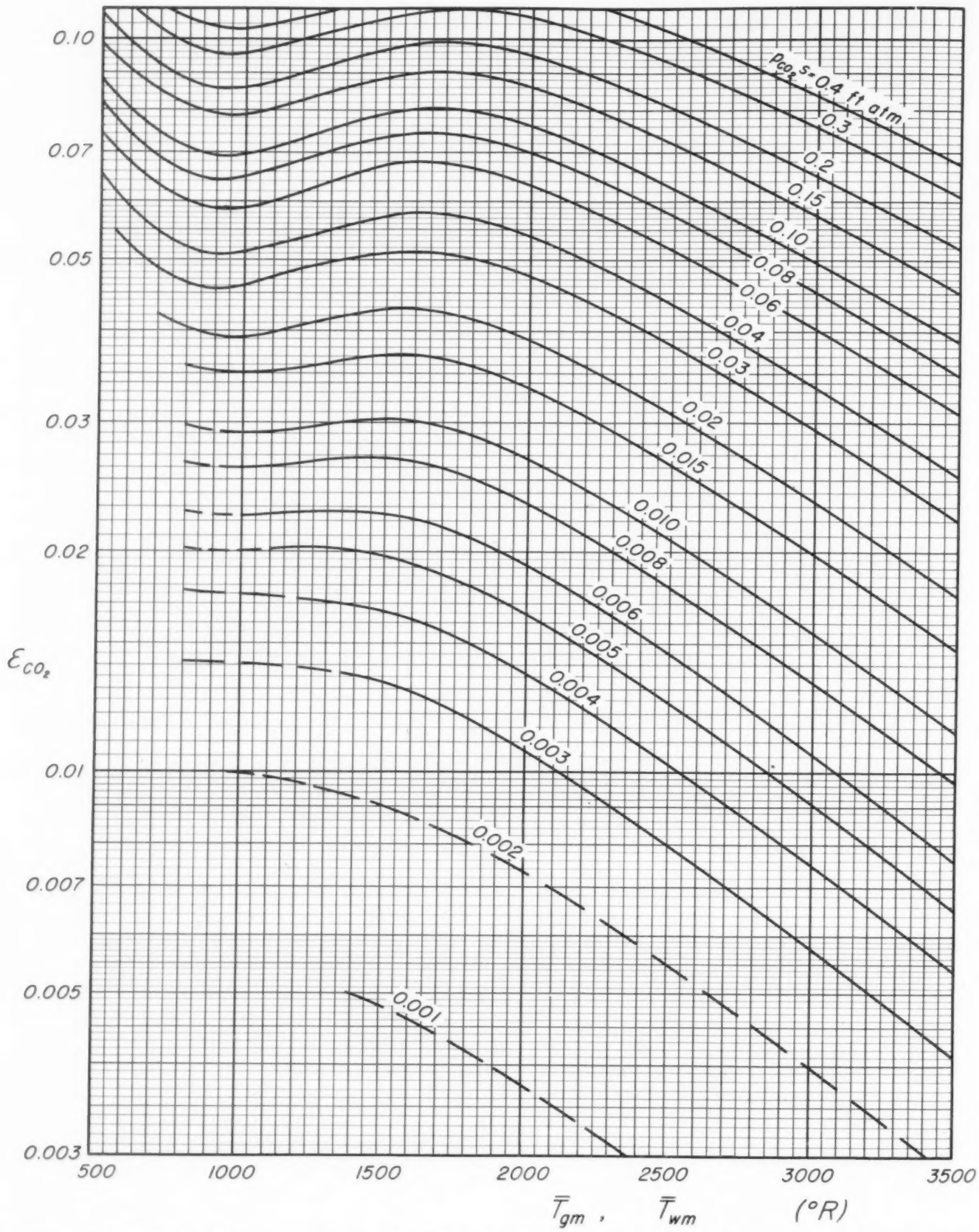


Figure 16 — Emissivity of CO_2 vs temperature. (After H. C. Hottel). Reprinted from W. H. McAdams, Heat Transmission, by kind permission of McGraw-Hill Publishing Co.

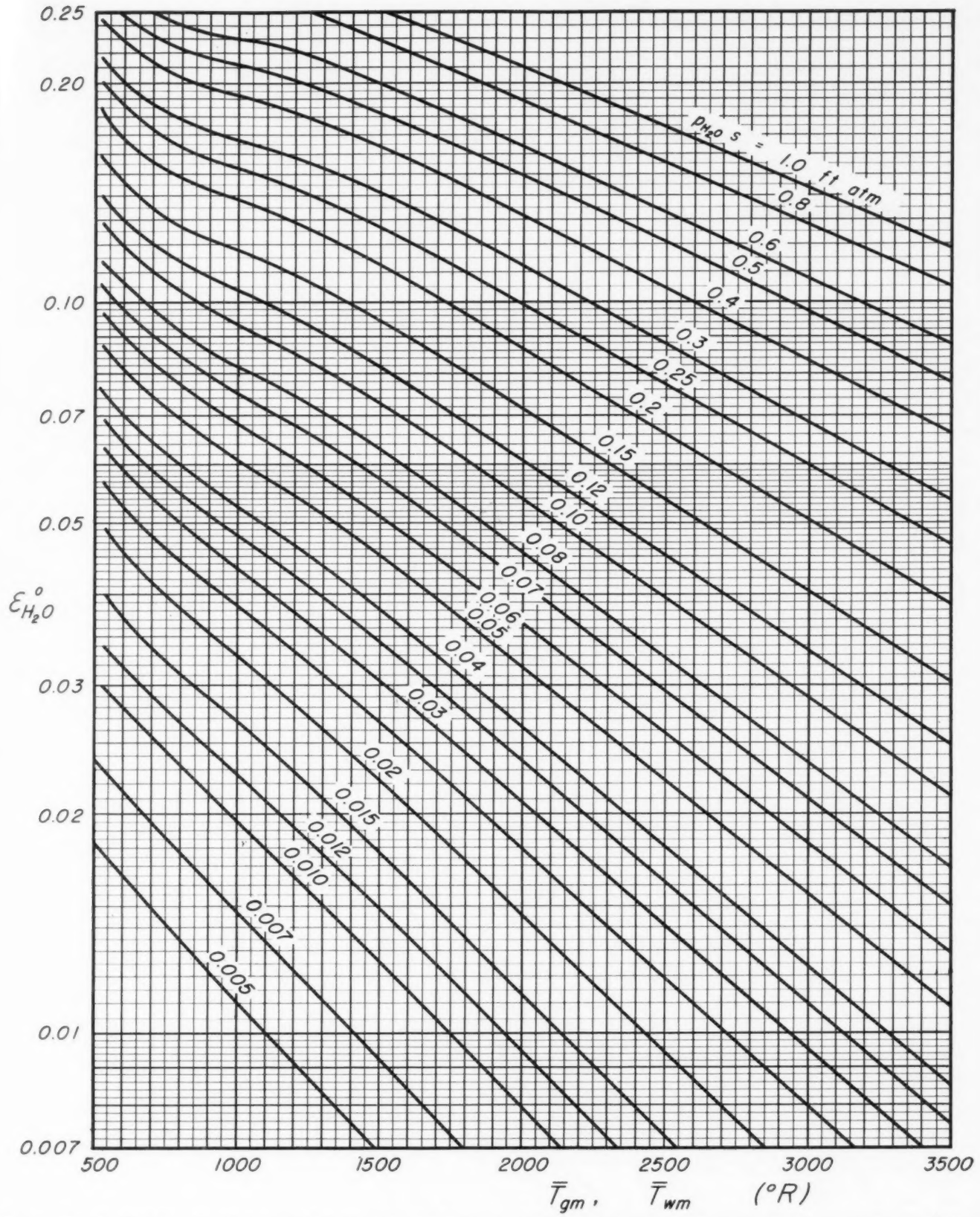


Figure 17 — Emissivity of water vapor for one-atm total gas pressure and zero partial pressure vs temperature. (After H. C. Hottel.) Reprinted from W. H. McAdams, Heat Transmission, by kind permission of McGraw-Hill Publishing Co.

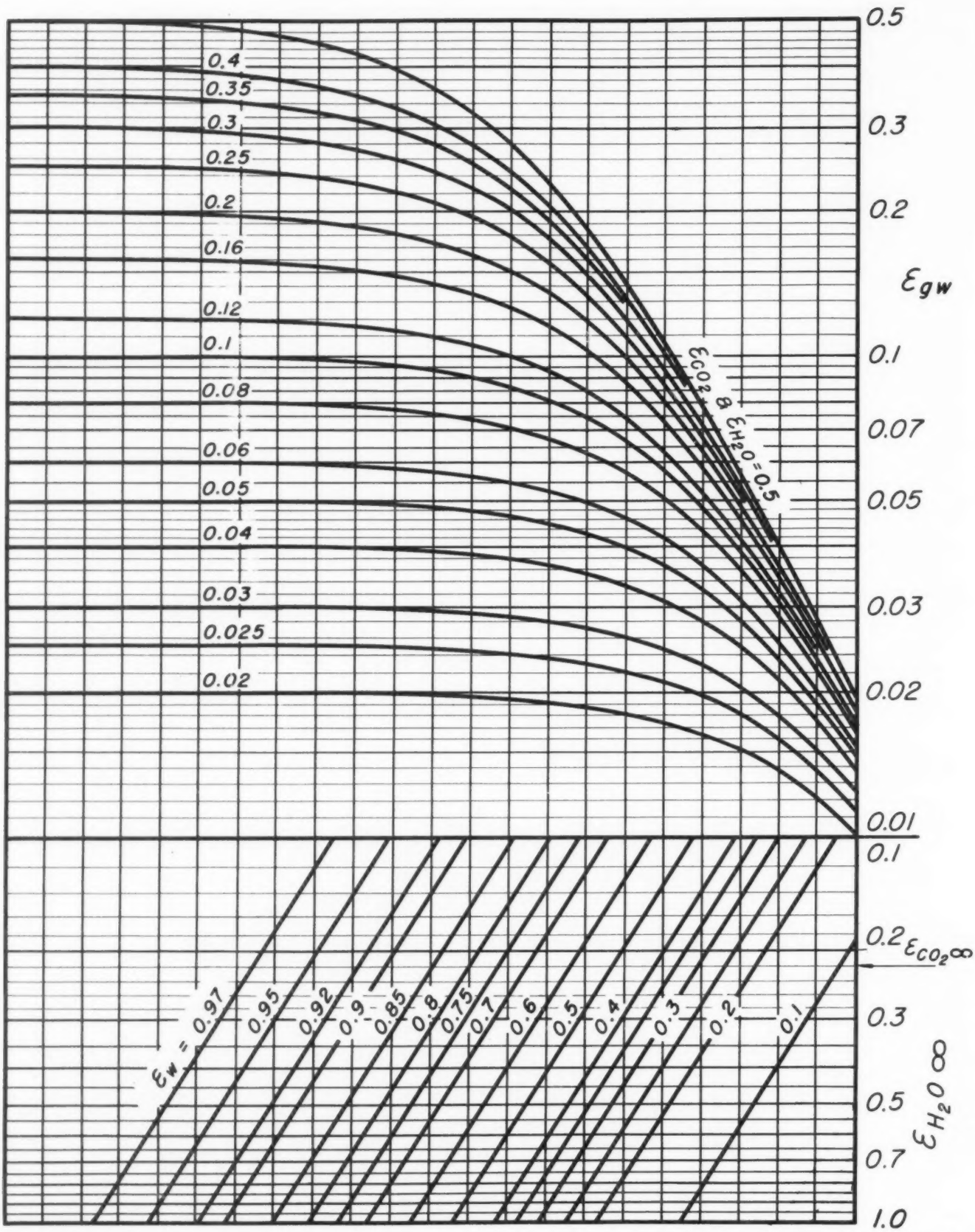


Figure 18 — Determination of combined gas-wall emissivity (after Landfermann and Blomert) from VDI-Waermeatlas, by kind permission of VDI Verlag, GmbH.

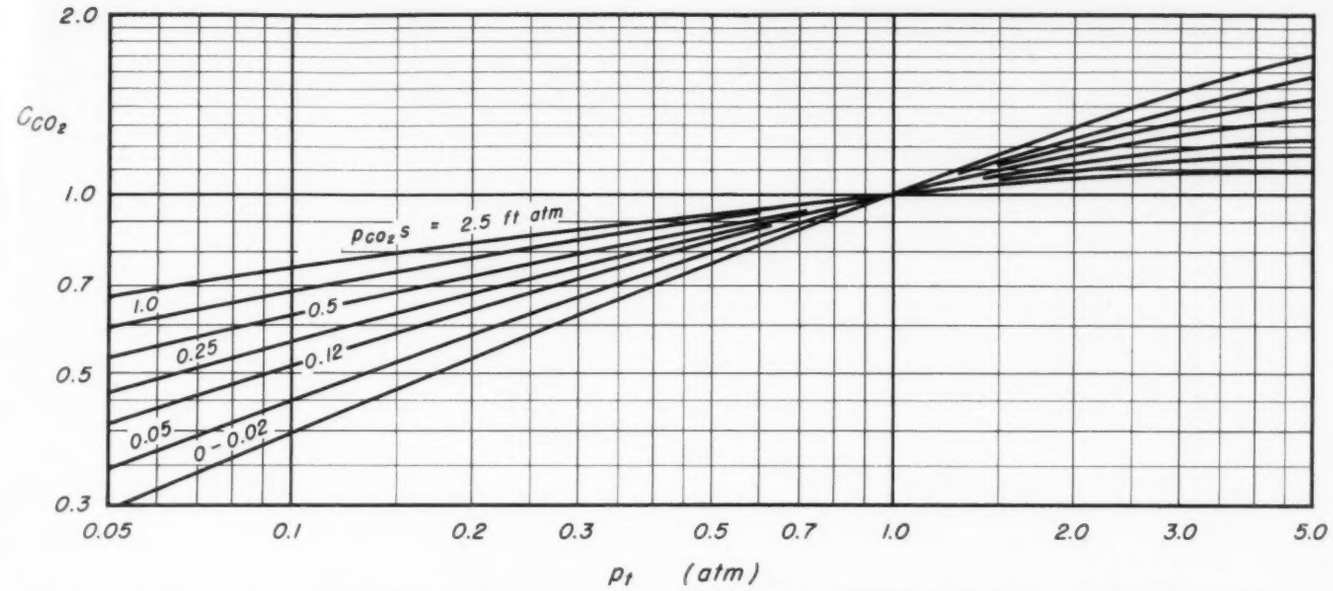
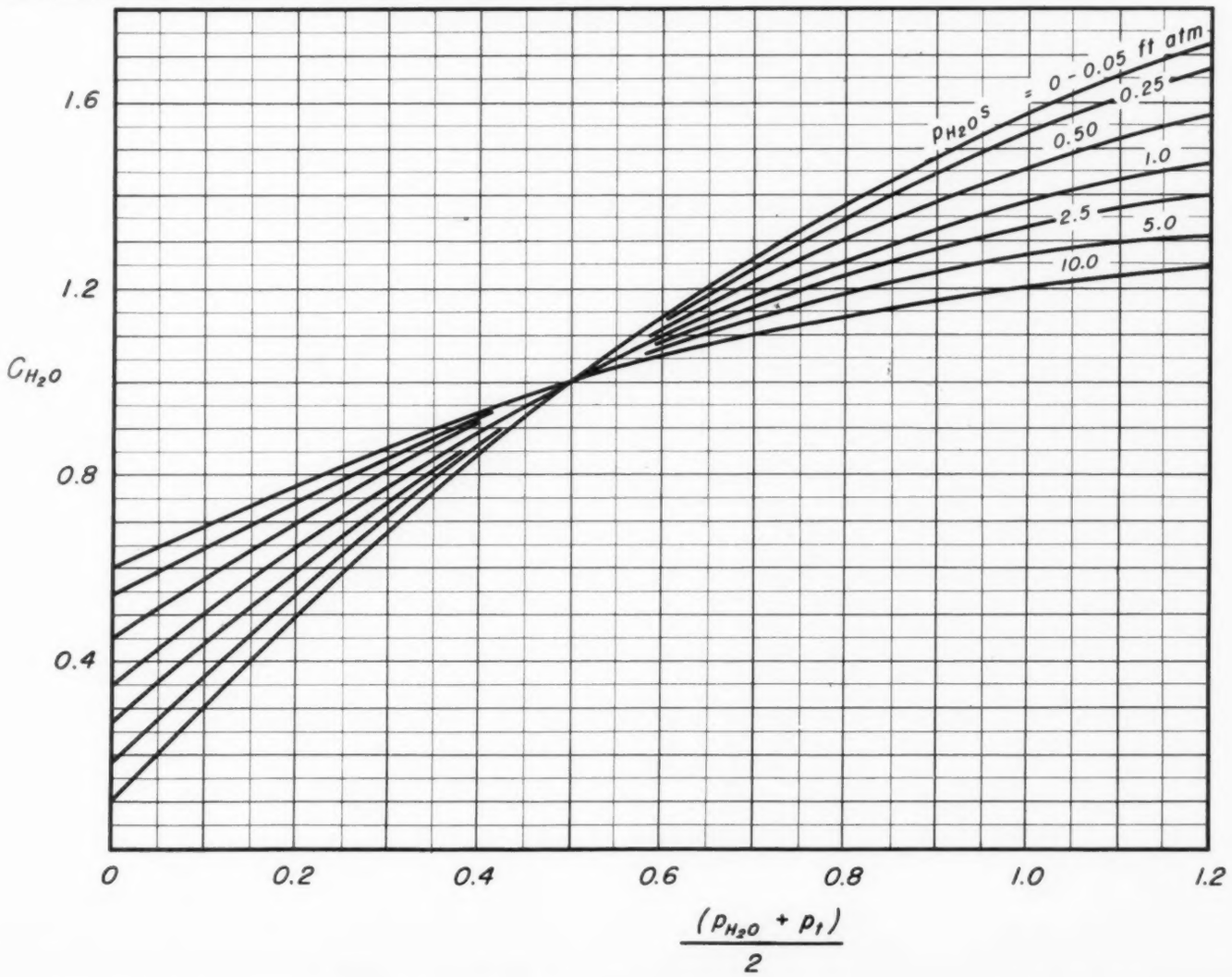


Figure 19 — Pressure correction factor for CO_2. (After H. C. Hottel.) Reprinted from W. H. McAdams, Heat Transmission, by kind permission of McGraw-Hill Publishing Co.

Figure 20 — Pressure correction factor of H_2O. (After H. C. Hottel.) Reprinted from W. H. McAdams, Heat Transmission, by kind permission of McGraw-Hill Publishing Co.



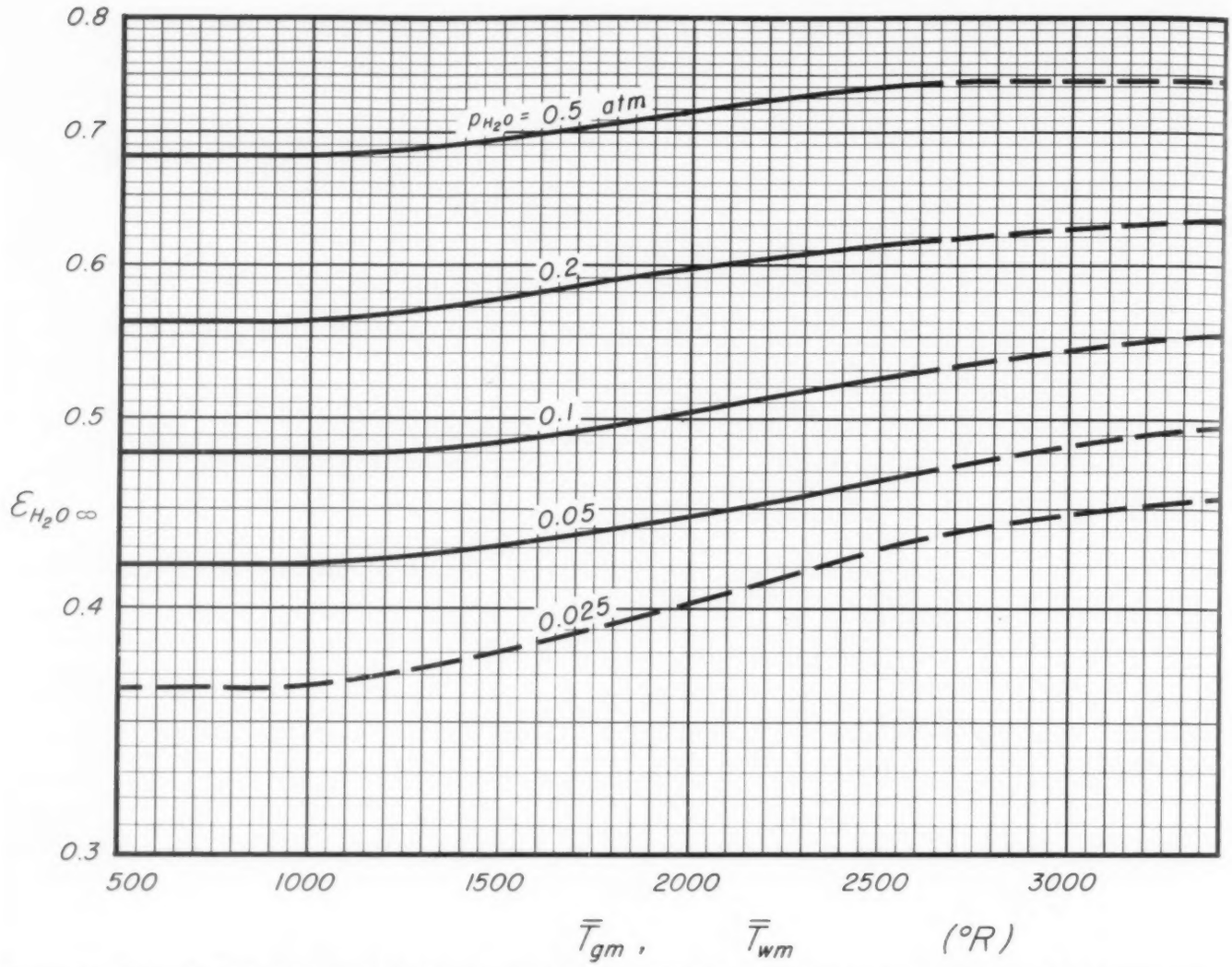


Figure 21 — Emissivity of water vapor at infinite layer thickness. (After E. Schmidt.) Reprinted from VDI-Waermeatlas, by kind permission of VDI Verlag, GmbH. (with modifications).

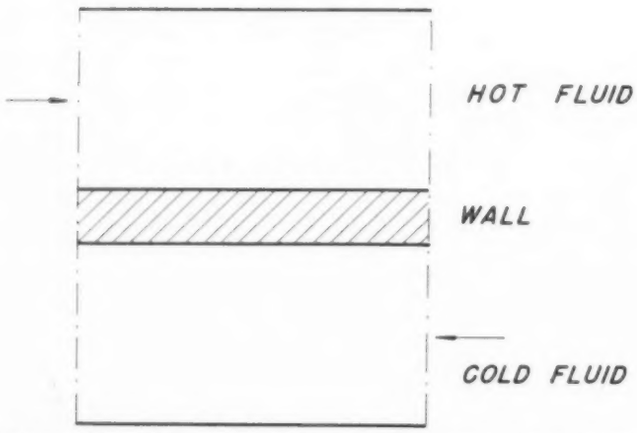


Figure 22 — Schematic diagram of a counter-flow heat exchanger.

TABLE I

Thermal Conductivity of Refractories, Btu per ft, hr, F

Temperature, F	Fireclay brick	Superduty fireclay brick	Silica brick	Magnesite brick	Silicon carbide brick	High alumina brick
0	0.565	0.64	0.534	4.65	9.63	1.030
200	0.597	0.66	0.590	4.12	9.61	0.995
400	0.627	0.68	0.647	3.66	9.59	0.970
600	0.652	0.70	0.703	3.21	9.57	0.950
800	0.680	0.72	0.759	2.90	9.55	0.935
1000	0.706	0.74	0.814	2.64	9.53	0.920
1200	0.733	0.77	0.873	2.43	9.38	0.907
1400	0.761	0.80	0.925	2.26	9.21	0.900
1600	0.786	0.83	0.977	2.15	9.01	0.897
1800	0.813	0.85	1.031	2.03	8.75	0.890
2000	0.842	0.88	1.084	1.94	8.43	0.887
2200	0.868	0.91	1.141	1.88	8.07	0.883
2400	0.894	0.95	1.195	1.84	7.71	0.879
2600	0.918	...	1.251	1.79	7.39	0.876
2800	0.949	...	1.292	1.74	6.99	0.874

Values shown are averages of data of a number of suppliers.

WORKSHEET 1
Basic Data and Assumptions

Line	Value	Units	Symbol	Description
1		cu ft per hr, sq ft	M	Volume flow rate of waste gas at 60 F
2			r	Air/gas ratio
3				Gas composition
4		lb per cu ft	ρ_g	Density of gas at 60 F
5		lb per cu ft	ρ_a	Density of air at 60 F
6		F	T_{gi}	Gas inlet temperature
7		F	T_{ai}	Air inlet temperature
8		hr	τ	Reversal period
9				Flue description
10				Flue wall thickness
11		ft	L	Flue length
12		sq ft	A	Free cross section of a single flue
13		sq ft	A_t	Total cross section of the checker
14			n	Number of flues in the checker
15		ft	P	Perimeter of a single flue
16			R	Ratio of free cross section to total cross section of the checker
17				Flue material
18		lb per cu ft	ρ_w	Density of flue material
19			ϵ_w	Emissivity of flue material
20				Type of surface roughness (Figure 1)
21			F_R	Correction factor for roughness
22			Figure	Specify Figure 3a or 3b, from Figure 1 and Line 20

TABLE II
Density of Refractory Materials, lb per cu ft

Fireclay brick	100–140
Silica brick	100–112
Magnesite brick	165–200
Silicon carbide brick	150–165

All values from AISE, Committee on Open Hearth Regenerators.

WORKSHEET 2
Final Results and Verification of Assumed Temperatures

Line	Instructions	Description	Result, F		
			Trial 1	Trial 2	Trial 3
1	Estimate T_{gm}	T_{gm}			
2	Enter Line 11 Sheet 10	T_{gm}			
3	Estimate T_{am}	T_{am}			
4	Enter Line 13 Sheet 10	T_{am}			
5	Estimate T_{wm}	T_{wm}			
6	Enter Line 15 Sheet 10	T_{wm}			
7	Enter Line 17 Sheet 10	T_{ge}			
8	Enter Line 21 Sheet 10	T_{ae}			
9	Enter Line 24 Sheet 10	Approximate T_w (maximum)			

WORKSHEET 3
Calculation of Convective Heat Transfer Coefficients

Line	Instructions	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter Line 1 Sheet 1	M		...	...
2	Enter Line 2 Sheet 1	r		...	...
3	Enter Line 12 Sheet 1	A		...	...
4	Enter Line 15 Sheet 1	P		...	...
5	Enter Line 16 Sheet 1	R		...	...
6	Enter Line 21 Sheet 1	F_R		...	...
7	Enter Line 22 Sheet 1	Figure		...	...
8	Enter Line 1 Sheet 2	T_{gm}			
9	Enter Line 3 Sheet 2	T_{am}			
10	Line 1 divided by Line 5	v_g		...	...
11	Four times Line 3			...	...
12	Line 11 divided by Line 4	D		...	...
13	Read F_1 on Figure indicated by Line 7. Use Lines 10 and 12	F_1		...	...
14	Read C_T on Figure 3. Use Line 8	C_T			
15	Line 14 times Line 13				
16	Line 15 times Line 6	h_{gc}			
17	Line 10 times Line 2	v_a		...	...
18	Read F_1 on Figure shown by Line 7. Use Lines 17 and 12	F_1		...	...
19	Read C_T on Figure 2. Use Line 9	C_T			
20	Line 19 times Line 18				
21	Line 20 times Line 6	h_{ac}			

WORKSHEET 4
Calculation of Radiative and Total Heat Transfer Coefficients

Line	Instructions	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter from Line 3 Sheet 1	Per cent CO_2		...	...
2	Enter from Line 3 Sheet 1	Per cent H_2O		...	...
3	Enter Line 1 Sheet 2	T_{gm}			
4	Enter Line 5 Sheet 2	T_{wm}			
5	Enter Line 12 Sheet 3	D		...	...
6	Read Q_{gm} on Figure 6. Use Lines 3 and 5	Q_{gm}			
7	Read Q_{wm} on Figure 6. Use Lines 4 and 5	Q_{wm}			
8	Line 6 minus Line 7				
9	Line 3 minus Line 4				
10	Line 8 divided by Line 9				
11	Read C on Figure 5. Use Lines 1 and 2	C		...	...
12	Line 11 times Line 10	h_{gr}			
13	Enter Line 16 Sheet 3	h_{gc}			
14	Line 12 plus Line 13	h_g			
15	Enter Line 21 Sheet 3	h_a			

TABLE III
Specific Heats of Refractory Materials, Btu per lb, F

Temperature, F	Fireclay brick and superduty fireclay brick	Silica brick	Magnesite brick	Silicon carbide	High alumina brick
32	0.193	0.169	0.208	0.15	0.184
200	0.205	0.207	0.230	...	0.208
400	0.217	0.237	0.250	...	0.236
600	0.231	0.254	0.266	...	0.243
800	0.247	0.266	0.278	...	0.248
1000	0.261	0.276	0.289	...	0.252
1200	0.275	0.287	0.298	...	0.256
1400	0.289	0.295	0.307	...	0.260
1600	0.294	0.303	0.315	...	0.263
1800	0.299	0.310	0.323	...	0.267
2000	0.302	0.316	0.330	...	0.271
2200	0.305	0.323	0.337	...	0.274
2400	0.307	0.328	0.344	0.275	0.277
2600	0.308	0.334	0.350	...	0.280
2800	...	...	...	...	0.283

Values shown are averages of data of a number of suppliers.

TABLE IV
Emissivity of Refractory Materials

Fireclay brick Silica brick Magnesite brick Silicon carbide brick	0.75 to 0.85

Unless better information is available, it is recommended to base calculations on a value of 0.8.

WORKSHEET 5
Calculation of Specific Heats of Gas and Air

Line	Instructions	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter Line 1 Sheet 2	T_{gm}			
2	Enter Line 3 Sheet 2	T_{am}			
3	Enter per cent CO_2 from Line 3 Sheet 1	Per cent CO_2		...	...
4	Enter per cent H_2O from Line 3 Sheet 1	Per cent H_2O		...	...
5	Enter per cent N_2 from Line 3 Sheet 1	Per cent N_2		...	...
6	Enter per cent O_2 from Line 3 Sheet 1	Per cent O_2		...	...
7		Per cent		...	...
8		Per cent		...	...
9	Read c_{CO_2} on Table VI. Use Line 1	c_{CO_2}			
10	Read c_{H_2O} on Table VI. Use Line 1	c_{H_2O}			
11	Read c_{N_2} on Table VI. Use Line 1	c_{N_2}			
12	Read c_{O_2} on Table VI. Use Line 1	c_{O_2}			
13					
14					
15	Line 3 times Line 9				
16	Line 4 times Line 10				
17	Line 5 times Line 11				
18	Line 6 times Line 12				
19	Line 7 times Line 13				
20	Line 8 times Line 14				
21	Add Lines 15, 16, 17, 18, 19 and 20				
22	Line 21 divided by 100	c_k			
23	Read c_a on Table VI. Use Line 2	c_a			

TABLE V
Density of Gases at 60 F and Standard Atmospheric Pressure, lb per cu ft[11]

Air	...	0.07644
Carbon monoxide	CO	0.07381
Carbon dioxide	CO_2	0.116
Hydrogen	H_2	0.005315
Nitrogen	N_2	0.07386
Oxygen	O_2	0.08433
Water vapor	H_2O	0.0475

Calculation of Characteristic Factors

Line	Instructions	Description	Result Trial 1	Trial 2	Trial 3
1	Enter Line 4 Sheet 1	ρ_g		...	...
2	Enter Line 11 Sheet 1	L		...	...
3	Enter Line 12 Sheet 1	A		...	...
4	Enter Line 13 Sheet 1	A_t		...	...
5	Enter Line 14 Sheet 1	n		...	...
6	Enter Line 15 Sheet 1	P		...	...
7	Enter Line 16 Sheet 1	R		...	...
8	Enter Line 17 Sheet 1			...	...
9	Enter Line 5 Sheet 2	T_{wm}			
10	Enter Line 10 Sheet 3	v_g		...	...
11	Enter Line 14 Sheet 4	h_g			
12	Enter Line 15 Sheet 4	h_a			
13	Enter Line 22 Sheet 5	c_g			
14	Read k_w in Table I. Use Lines 8 and 9	k_w			
15	1.0 minus Line 7			...	...
16	Line 15 times Line 4			...	...
17	Line 5 times Line 6			...	...
18	Line 16 divided by Line 17	y_0		...	...
19	Line 2 divided by Line 18	K_1		...	...
20	Line 12 divided by Line 11				
21	1.0 plus Line 20				
22	1.0 divided by Line 21	K_2			
23	Line 1 times Line 13				
24	Line 23 times Line 10				
25	Line 24 times Line 3				
26	Line 25 times Line 18				
27	Line 2 times Line 14				
28	Line 27 times Line 6				
29	Line 28 divided by Line 26	K_3			

Calculation of Characteristic Factors

Line	Instructions	Description	Result Trial 1	Trial 2	Trial 3
1	Enter Line 5 Sheet 1	ρ_a		...	...
2	Enter Line 8 Sheet 1	τ		...	...
3	Enter Line 12 Sheet 1	A		...	...
4	Enter Line 17 Sheet 1			...	...
5	Enter Line 18 Sheet 1	ρ_w		...	...
6	Enter Line 5 Sheet 2	T_{wm}			
7	Enter Line 17 Sheet 3	v_a		...	...
8	Enter Line 14 Sheet 4	h_g			
9	Enter Line 15 Sheet 4	h_a			
10	Enter Line 23 Sheet 5	c_a			
11	Enter Line 14 Sheet 6	k_w			
12	Enter Line 18 Sheet 6	y_o		...	...
13	Enter Line 28 Sheet 6				
14	Read c_w in Table III. Use Lines 4 and 6	c_w			
15	Line 1 times Line 10				
16	Line 15 times Line 7				
17	Line 16 times Line 3				
18	Line 17 times Line 12				
19	Line 13 divided by Line 18	K_4			
20	Line 11 divided by Line 12				
21	Line 20 divided by Line 8	K_5			
22	Line 20 divided by Line 9	K_6			
23	Line 5 times Line 14				
24	Line 11 divided by Line 23	α			
25	Line 12 times Line 12			...	...
26	Line 24 times Line 2				
27	Line 26 divided by Line 25	K_7			

TABLE VI

Specific Heat of Gases as Function of Temperature at Standard Atmospheric Pressure (Btu per lb, F)[12]

Temperature, F	Air*	CO_2	H_2O	Temperature, F	Air*	CO_2	H_2O
32	0.240	0.194	...	1600	0.278	0.301	0.56
100	0.240	0.203	...	1700	0.280	0.303	0.57
200	0.241	0.216	...	1800	0.282	0.305	0.58
300	0.243	0.227	0.456	1900	0.284	0.307	0.59
400	0.245	0.237	0.462	2000	0.286	0.309	0.60
500	0.247	0.247	0.470	2100	0.287	0.311	0.61
600	0.250	0.256	0.477	2200	0.288	0.313	0.62
700	0.253	0.263	0.485	2300	0.290	0.314	0.62
800	0.256	0.269	0.494	2400	0.291	0.316	0.63
900	0.259	0.275	0.50	2500	0.292	0.317	0.64
1000	0.262	0.280	0.51	2600	0.293	0.318	0.64
1100	0.265	0.284	0.52	2700	0.294	0.319	0.65
1200	0.268	0.288	0.53	2800	0.295	0.320	0.65
1300	0.271	0.292	0.54	2900	0.296	0.321	0.66
1400	0.274	0.295	0.55	3000	0.297	0.322	0.67
1500	0.276	0.298	0.56				

* Also applies to N_2, CO and O_2.

WORKSHEET 8

Calculation of Length Correction ($K_5' + K_6'$)

Line	Instructions	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter Line 19 Sheet 6	K_1		...	...
2	Enter Line 29 Sheet 6	K_3			
3	Enter Line 19 Sheet 7	K_4			
4	Enter Line 21 Sheet 7	K_5			
5	Enter Line 22 Sheet 7	K_6			
6	Line 4 plus Line 5	$K_5 + K_6$			
7	Line 3 divided by Line 2	K_4/K_3			
8	If Line 7 equals 1.0, skip to Line 22				
9	1.0 minus Line 7				
10	Line 6 divided by Line 2				
11	Line 1 times Line 1				
12	Line 3 divided by Line 11				
13	Line 12 plus Line 10				
14	Line 9 divided by Line 13	B_2			
15	Line 7 times Line 4				
16	Line 15 minus Line 5				
17	Line 16 divided by Line 9				
18	Line 17 divided by Line 11	B_3			
19	Read B_1 on Figure 7. Use Lines 14 and 18	B_1			
20	Line 2 times Line 9				
21	Line 20 divided by Line 19	$(K_5' + K_6')$			
22	If Line 7 equals 1.0, use the following:				
23	Line 1 times Line 1				
24	Line 2 times Line 2				
25	Line 24 divided by Line 23				
26	Line 25 plus Line 6	$(K_5' + K_6')$			

WORKSHEET 9

Calculation of Time Correction ($K_5'' + K_6''$) and Mean Temperature Ratios

Line	Instruction	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter Line 22 Sheet 6	K_2			
2	Enter Line 29 Sheet 6	K_3			
3	Enter Line 19 Sheet 7	K_4			
4	Enter Line 27 Sheet 7	K_7			
5	Enter Line 7 Sheet 8	K_4/K_3			
6	Enter Line 21 or Line 26 Sheet 8	$(K_5' + K_6')$			
7	1.0 divided by Line 4	$1/K_7$			
8	Read G_1 on Figure 8. Use Line 7	G_1			
9	Line 6 plus Line 8			....	....
10	2.0 times Line 4				
11	Line 10 divided by Line 9. If Line 11 is less than 0.1, skip to Line 17 and write Line 17 equals 1.0	G_2			
12	1.0 divided by Line 2				
13	1.0 divided by Line 3				
14	Line 12 plus Line 13				
15	Line 14 times Line 9				
16	4.0 divided by Line 15	G_3			
17	Read G_4 on Figure 9 or 10. Use Lines 11 and 16	G_4			
18	Line 9 divided by Line 17	$(K_5'' + K_6'')$			
19	Line 18 divided by Line 2	$\frac{(K_5'' + K_6'')}{K_3}$			
20	Read θ_{gm} on Figure 11. Use Lines 19 and 5	θ_{gm}			
21	Read θ_{am} on Figure 12. Use Lines 19 and 5	θ_{am}			
22	Read θ_{ge} on Figure 13. Use Lines 19 and 5	θ_{ge}			
23	Line 20 minus Line 21				
24	Line 23 times Line 1				
25	Line 24 plus Line 21	θ_{wm}			

WORKSHEET 10
Calculation of Temperatures

Line	Instructions	Description	Result		
			Trial 1	Trial 2	Trial 3
1	Enter Line 6 Sheet 1	T_{gi}		...	...
2	Enter Line 7 Sheet 1	T_{ai}		...	...
3	Enter Line 22 Sheet 6	K_2			
4	Enter Line 7 Sheet 8	K_4/K_3			
5	Enter Line 20 Sheet 9	θ_{gm}			
6	Enter Line 21 Sheet 9	θ_{am}			
7	Enter Line 22 Sheet 9	θ_{ge}			
8	Enter Line 25 Sheet 9	θ_{wm}			
9	Line 1 minus Line 2			...	...
10	Line 5 times Line 9				
11	Line 10 plus Line 2. Enter result on Line 2 Sheet 2	T_{gn}	F	F	F
12	Line 6 times Line 9				
13	Line 12 plus Line 2. Enter result on Line 4 Sheet 2	T_{am}	F	F	F
14	Line 8 times Line 9				
15	Line 14 plus Line 2. Enter result on Line 6 Sheet 2	T_{wm}	F	F	F
16	Line 7 times Line 9				
17	Line 16 plus Line 2. Enter result on Line 7 Sheet 2	T_{ge}	F	F	F
18	1.0 minus Line 7				
19	Line 18 times Line 4	θ_{ae}			
20	Line 19 times Line 9				
21	Line 20 plus Line 2. Enter result on Line 8 Sheet 2	T_{ae}	F	F	F
22	Line 1 minus Line 21				
23	Line 22 times Line 3				
24	Line 23 plus Line 21. Enter result on Line 9 Sheet 2	Approximate T_w (maximum	F	F	F

WORKSHEET 11
Uncertainty in Calculated Air Exit Temperature

Line	Instruction	Description	Result
1	Enter from Line 3 Sheet 1	Per cent CO_2	
2	Enter from Line 3 Sheet 1	Per cent H_2O	
3	Enter Line 6 Sheet 1	T_{gi}	
4	Enter Line 7 Sheet 1	T_{ai}	
5	Enter Line 16 Sheet 3	h_{ge}	
6	Enter Line 12 Sheet 4	h_{gr}	
7	Enter Line 29 Sheet 6	K_3	
8	Enter Line 21 Sheet 7	K_5	
9	Enter Line 9 Sheet 8	$1 - \frac{K_4}{K_3}$	
10	Enter Line 17 Sheet 9	G_4	
11	Enter Line 19 Sheet 9	$\frac{(K_5'' + K_6'')}{K_3}$	
12	Line 9 divided by Line 11	F_2	
13	Read F_3 on Figure 14. Use Lines 12 and 11	F_3	
14	Read $U_{h_{gr}}$ on Figure 15. Use Lines 1 and 2	$U_{h_{gr}}$	
15	Line 8 divided by Line 7		
16	Line 5 divided by Line 6		
17	1.0 plus Line 16		
18	1.0 divided by Line 17		
19	Line 3 minus Line 4		
20	Line 13 times Line 14		
21	Line 20 times Line 15		
22	Line 21 times Line 18		
23	Line 22 times Line 19		
24	Line 23 divided by Line 10		
25	Line 24 divided by 100	$U_{T_{ae}}$	F

TABLE VII

$K_5/K_3 = 0.16 \quad K_1^2/K_3 = 7.2$

(A)

$\frac{K_4}{K_3}$	$\frac{K_5 + K_6}{K_3}$	θ_{ge}		Deviation		θ_{ae}		Deviation	
		Analog	Calculated	Dimensionless*	Degrees, F†	Analog	Calculated	Dimensionless*	Degrees, F†
0.0016	0.1619	0	0	0	0	0	0.002	0.002	5.0
0.0016	0.2931	0.05	0.056	0.006	15.0	0	0.002	0.002	5.0
0.0016	1.49	0.532	0.536	0.004	10.0	0	0.001	0.001	2.5
0.0016	3.556	0.760	0.753	0.007	17.5	0	0	0	0
0.2	0.1619	0.0170	0.007	0.01	25.0	0.197	0.199	0.002	5.0
0.2	0.2931	0.09	0.085	0.005	12.5	0.182	0.183	0.001	2.5
0.2	1.49	0.554	0.554	0	0	0.089	0.089	0	0
0.2	3.556	0.776	0.767	0.001	2.5	0.047	0.047	0	0
2.0	0.1619	0.540	0.540	0	0	0.920	0.920	0	0
2.0	0.2931	0.554	0.554	0	0	0.892	0.891	0.001	2.5
2.0	1.49	0.682	0.691	0.009	22.5	0.636	0.618	0.018	45.0‡
2.0	3.556	0.811	0.813	0.002	5.0	0.378	0.374	0.004	10.0
16	0.1619	0.938	0.939	0.001	2.5	0.998	0.982	0.016	40.0‡
16	0.2931	0.938	0.939	0.001	2.5	0.996	0.981	0.015	37.5‡
16	1.49	0.938	0.939	0.001	2.5	0.992	0.971	0.019	47.5‡
16	3.556	0.940	0.941	0.001	2.5	0.968	0.940	0.028	70.0‡

TABLE VII (Continued)

$K_5/K_3 = 0.001 \quad K_1^2/K_3 = 7.2$

(B)

$\frac{K_4}{K_3}$	$\frac{K_5 + K_6}{K_3}$	θ_{ge}		Deviation		θ_{ae}		Deviation	
		Analog	Calculated	Dimensionless*	Degrees, F†	Analog	Calculated	Dimensionless*	Degrees, F†
0.0016	0.134	0.01	0.010	0	0	0	0.002	0.002	5.0
0.0016	1.331	0.504	0.489	0.015	37.5	0	0.001	0.001	2.5
0.0016	3.40	0.752	0.754	0.002	5.0	0	0	0	0
0.2	0.134	0.030	0.024	0.006	15.0	0.194	0.195	0.001	2.5
0.2	1.331	0.528	0.523	0.005	12.5	0.095	0.095	0	0
0.2	3.40	0.756	0.759	0.003	7.5	0.049	0.048	0.001	2.5
2.0	0.134	0.522	0.517	0.005	12.5	0.956	0.967	0.011	27.5
2.0	1.331	0.678	0.671	0.007	17.5	0.644	0.658	0.014	35.0‡
2.0	3.40	0.806	0.803	0.003	7.5	0.388	0.395	0.007	17.5
16	0.134	0.938	0.938	0	0	1.00	0.999	0.001	2.5
16	1.331	0.938	0.938	0	0	0.994	0.998	0.004	10.0
16	3.40	0.940	0.939	0.001	2.5	0.966	0.983	0.017	42.5‡

* Dimensionless = θ_{ge} analog − θ_{ge} calculated = analog − calculated.
† Degrees = dimensionless × 2500.
‡ These values, showing deviations larger than 30 F refer to "unreasonable" regenerators—see text.

TABLE VIII

Comparison of Computed with Analog Results for the Gas Side of Regenerators

K_3	$\frac{K_4}{K_3}$	$\frac{K_5}{K_3}$	$\frac{K_5 + K_6}{K_3}$	$\frac{K_1^2}{K_3}$	K_7	θ_{ge}		Deviation	
						Analog	Computed	Dimensionless	Degrees, F
0.8	1.0	0.625	1.875	4500	0.06	0.694	0.705	0.011	27.5
0.8	1.0	0.625	1.875	4500	20	0.990	0.965	0.025	62.5
0.8	1.0	0.625	1.875	1.125×10^5	20	0.995	0.964	0.031	77.5
0.8	1.0	0.625	2126	4500	0.06	1.0	1.0	0	0
0.8	1.0	0.625	2126	4500	20	1.0	1.0	0	0
0.8	1.0	0.625	2126	1.125×10^5	20	1.0	1.0	0	0
0.8	1.0	100	101.3	4500	0.06	0.99	0.99	0	0
0.8	1.0	100	101.3	4500	20	0.99	0.99	0	0
0.8	1.0	100	101.3	1.125×10^5	20	0.99	0.99	0	0
0.8	1.0	100	2225	4500	0.06	1.0	1.0	0	0
0.8	1.0	100	2225	4500	20	1.0	1.0	0	0
0.8	1.0	100	2225	1.125×10^5	20	1.0	1.0	0	0
0.8	10^4	0.625	1.875	4500	0.06	1.0	1.0	0	0
0.8	10^4	0.625	1.875	4500	20	1.0	1.0	0	0
0.8	10^4	0.625	1.875	1.125×10^5	20	1.0	1.0	0	0
0.8	10^4	0.625	2126	4500	0.06	1.0	1.0	0	0
0.8	10^4	0.625	2126	4500	20	1.0	1.0	0	0
0.8	10^4	0.625	2126	1.125×10^5	20	1.0	1.0	0	0
0.8	10^4	100	101.3	4500	0.06	1.0	1.0	0	0
0.8	10^4	100	101.3	4500	20	1.0	1.0	0	0
0.8	10^4	100	101.3	1.125×10^5	20	1.0	1.0	0	0
0.8	10^4	100	2225	4500	0.06	1.0	1.0	0	0
0.8	10^4	100	2225	4500	20	1.0	1.0	0	0
0.8	10^4	100	2225	1.125×10^5	20	1.0	1.0	0	0
80	1.0	0.625×10^{-2}	21.26	45	0.06	0.957	0.955	0.002	5.0
80	1.0	0.625×10^{-2}	21.26	45	20	0.950	0.955	0.005	12.5
80	1.0	0.625×10^{-2}	21.26	1125	20	0.950	0.955	0.005	12.5
80	1.0	1.0	1.013	45	0.06	0.520	0.509	0.011	27.5
80	1.0	1.0	1.013	45	20	0.525	0.514	0.011	27.5
80	1.0	1.0	1.013	1125	20	0.520	0.508	0.012	30.0
80	1.0	1.0	22.25	45	0.06	0.961	0.957	0.004	10.0
80	1.0	1.0	22.25	45	20	0.952	0.957	0.005	12.5
80	1.0	1.0	22.25	1125	20	0.952	0.957	0.005	12.5
80	40	0.625×10^{-2}	1.875×10^{-2}	45	0.06	0.975	0.975	0	0
80	40	0.625×10^{-2}	1.875×10^{-2}	45	20	0.975	0.975	0	0
80	40	0.625×10^{-2}	1.875×10^{-2}	1125	20	0.975	0.975	0	0
80	40	0.625×10^{-2}	21.26	45	0.06	0.978	0.980	0.002	5.0
80	40	0.625×10^{-2}	21.26	45	20	0.979	0.980	0.001	2.5
80	40	0.625×10^{-2}	21.26	1125	20	0.975	0.979	0.004	10.0
80	40	1.0	1.013	45	0.06	0.976	0.975	0.001	2.5
80	40	1.0	1.013	45	20	0.975	0.975	0	0
80	40	1.0	1.013	1125	20	0.975	0.975	0	0
80	40	1.0	22.25	45	0.06	0.979	0.980	0.001	2.5
80	40	1.0	22.25	45	20	0.979	0.980	0.001	2.5
3200	2.5×10^{-4}	0.156×10^{-3}	0.468×10^{-3}	28.13	20	0	0	0	0
3200	2.5×10^{-4}	0.156×10^{-3}	0.5314	28.13	20	0.168	0.175	0.007	17.5
3200	2.5×10^{-4}	0.025	0.0253	28.13	20	0	0	0	0
3200	2.5×10^{-4}	0.025	0.5563	28.13	20	0.170	0.181	0.011	27.5
3200	0.025	0.156×10^{-3}	0.468×10^{-3}	28.13	20	0	0	0	0
3200	0.025	0.156×10^{-3}	0.5563	28.13	20	0.167	0.176	0.009	22.5
3200	0.025	0.025	0.0253	28.13	20	0	0	0	0
3200	0.025	0.025	0.5563	28.13	20	0.173	0.188	0.015	37.5
3200	2.5	0.156×10^{-3}	0.468×10^{-3}	28.13	20	0.6	0.6	0	0
3200	2.5	0.156×10^{-3}	0.5314	28.13	20	0.620	0.618	0.002	5.0
3200	2.5	0.025	0.0253	28.13	20	0.6	0.6	0	0
3200	2.5	0.025	0.5563	28.13	20	0.626	0.620	0.006	15.0

APPENDIX

General procedure for radiation heat transfer coefficient—If the simple approximate procedure shown in Worksheets 4 and 2 is not applicable or if the errors are too large, the following procedure should be used:

1. In this procedure the value of h_{gr} is separately determined for the CO_2 and H_2O components. The total heat transfer coefficient due to radiation is:

$$h_{gr} = h_{CO_2} + h_{H_2O} \text{ Btu per sq ft, hr, F} \quad \text{(A-1)}$$

The h_{H_2O} is obtained in similar fashion as h_{CO_2}; however, for water vapor additional factors are needed.

2. Select the emissivity of the flue wall. Data on emissivity of refractory materials are scarce and at times doubtful and the reader may wish to rely on his own sources. However, an ϵ_w of 0.8 as mentioned in the manual is suggested.

3. Compute the gas layer thickness. For regenerator flues where the length is substantially greater than the other dimensions, the gas layer thickness is given by:

$$s = 0.9\ D \qquad s \text{ and } D \text{ are in feet}$$

4. Determine the product (ps) for CO_2 and H_2O: p is the partial pressure of the gas component in atmospheres and s the layer thickness in feet. At atmospheric pressure, which may usually be assumed in regenerators, the partial pressure of the gas components equals numerically the fractional volume.

5. *Carbon dioxide*—Determine the emissivity of carbon dioxide from Figure 16. In this figure the space-time mean temperatures in degrees Rankine are plotted as abscissas and the emissivities (ϵ_{CO_2}) of carbon dioxide as ordinates for constant values of $p_{CO_2}s$. Figure 19 allows, if required, a correction factor (C_{CO_2}) to be introduced in case the total pressure of the gas deviates appreciably from standard conditions. In this figure C_{CO_2} is plotted as a function of the total pressure for various values of $p_{CO_2}s$. The emissivity (ϵ_{CO_2}) obtained from Figure 16 is to be multiplied by C_{CO_2}, if such correction is necessary. Use this chart twice, once using $\bar{T}_{gm}$, and again using $\bar{T}_{wm}$; thus in this step one obtains two emissivities for carbon dioxide, one based on $\bar{T}_{gm}$ and one based on $\bar{T}_{wm}$.

6. Heat transfer from radiating gases is controlled by an emissivity which results from gas and brick emissivities. This combined emissivity can be found from Figure 18, which is used now for CO_2 and later for H_2O. Start in the lower part of the chart; on the right ordinate scale the value 0.22 is marked by an arrow $\epsilon_{CO_2\infty}$ which is the emissivity of an infinitely thick layer of CO_2. Proceed horizontally along the line $\epsilon_{CO_2\infty} = 0.22$ until it intersects with the chosen value of the brick emissivity, ϵ_w, erect a vertical and proceed into the upper half of Figure 18 and to the value of ϵ_{CO_2} determined from Figure 16. Draw a horizontal to the right and read on this upper ordinate scale the value of ϵ_{CO_2w}. Since two values of ϵ_{CO_2} were obtained (one using the space-time mean temperature of the gas and one that of the brick) one will find two values of ϵ_{CO_2w}.

7. Next compute Q_{gm} and Q_{wm} from Equation A-2:

$$Q_{gm} = 0.173\ \epsilon_{CO_2w}\ (\bar{T}_{gm}/100)^4 \quad \text{(A-2a)}$$

$$Q_{wm} = 0.173\ \epsilon_{CO_2w}\ (\bar{T}_{wm}/100)^4 \quad \text{(A-2b)}$$

In (A-2a) use ϵ_{CO_2w} found on Figure 18 when using $\bar{T}_{gm}$; in (A-2b) use ϵ_{CO_2w} found on Figure 18 when using $\bar{T}_{wm}$. Now the value of h_{CO_2} can be found from Equation A-3:

$$h_{CO_2} = \frac{(Q_{gm} - Q_{wm})}{(\bar{T}_{gm} - \bar{T}_{wm})} \quad \text{(A-3)}$$

8. *Water vapor*—Before proceeding to the graphs, compute $(1/2)(p_{H_2O} + p_t)$ where p_{H_2O} is the partial pressure of the water vapor, and p_t is the total pressure, both in atmospheres.

9. Determine at $\bar{T}_{gm}$ and $\bar{T}_{wm}$ values of $\epsilon^\circ_{H_2O}$, the emissivity of water vapor at zero partial pressure and a total pressure of the gas of one atm, using Figure 17. Now apply a correction factor (C_{H_2O}) shown in Figure 20, to account for the actual partial pressure. In this figure values of C_{H_2O} are plotted (ordinates) against $(1/2)(p_{H_2O} + p_t)$ (abscissas) for various values of $p_{H_2O}s$. For the value of $(1/2)\ (p_{H_2O} + p_t)$ determined in step 8 and $p_{H_2O}s$ from step 4, obtain C_{H_2O}. The water vapor emissivities are:

$$\epsilon_{H_2O} = C_{H_2O}\ \epsilon^\circ_{H_2O} \quad \text{(A-4)}$$

Two values of ϵ_{H_2O} are obtained, one based on $\bar{T}_{gm}$ and one based on $\bar{T}_{wm}$.

10. Determine the water vapor emissivity for an infinite layer thickness from Figure 21. In this figure the space-time mean temperatures are plotted as abscissas and $\epsilon_{H_2O\infty}$ as ordinates for various values of the partial pressure of water vapor. Determine two values for $\epsilon_{H_2O\infty}$; one based on $\bar{T}_{gm}$ and one based on $\bar{T}_{wm}$.

11. Determine the combined emissivity (ϵ_{H_2Ow}) of water vapor and brick from Figure 18. (This corresponds to step 6 for CO_2.) Again two values ϵ_{H_2Ow} are obtained, one computed with $\bar{T}_{gm}$ and one with $\bar{T}_{wm}$. Both are found in the same manner, using Figure 18. Read on the lower ordinate scale the appropriate value of $\epsilon_{H_2O\infty}$, as determined from Figure 21. Draw a horizontal to the left to the intersection with the appropriate value of ϵ_w. From this intersection draw a vertical into the upper half of the figure and to the curve having the value of ϵ_{H_2O}, as found from Equation A-4. From this point draw a horizontal line to the right and read ϵ_{H_2Ow} on the ordinate scale.

12. Use Equation A-5 to compute values of Q_{gm} and Q_{wm}.

$$Q_{gm} = 0.173\ \epsilon_{H_2Ow}\ (\bar{T}_{gm}/100)^4 \quad \text{(A-5a)}$$

$$Q_{wm} = 0.173\ \epsilon_{H_2Ow}\ (\bar{T}_{wm}/100)^4 \quad \text{(A-5b)}$$

Then determine h_{H_2O} from Equation A-6, using the Q values from Equations A-5:

$$h_{H_2O} = \frac{(Q_{gm} - Q_{wm})}{(\bar{T}_{gm} - \bar{T}_{wm})} \quad \text{(A-6)}$$

13. Determine h_{gr} by summation of h_{CO_2}, Equation A-3 and h_{H_2O}, Equation A-6.

$$h_{gr} = h_{CO_2} + h_{H_2O} \quad \text{(A-7)}$$

PART TWO — DEVELOPMENT OF THE MANUAL

In Part One a method for the design of regenerators based on thermal considerations was presented. In this part the basis and background of the procedure which culminated in the design manual is described.

As a partial listing one can say that in the design and operation of regenerators three major problems arise:

1. The channeling.
2. The fouling.
3. The heat exchange within the flues.

These problems are interrelated, but this paper deals only with the latter, disregarding channeling and fouling. Thus, one can consider this paper as applying to a single flue or to a regenerator without channeling.

THE REGENERATOR AS MODIFIED HEAT EXCHANGER

Insofar as is known, all papers dealing with analytical solutions or approximations to the regenerator behavior are based on the concept of the regenerator as a heat exchanger. In order to explain this term, it will be stated that a heat exchanger is a system in which two fluids exchange heat through a thin separating wall, see Figure 22. The heat exchanger is usually considered to be in "steady state," which means that an observer located in the tube wall would not see any change of temperature with time. An observer traveling with the fluid stream would see the increase or decrease of the fluid temperature and would classify the process as transient. For the sake of comparison with regenerators, one needs to deal only with counterflow heat exchangers, that is, exchangers in which the two fluids flow in opposite directions, as illustrated by Figure 22. Although a regenerator operates "cyclically," one generally has to deal only with "cyclic equilibrium"; this condition is achieved when in the gas or the air stream and at any given location in the flue wall, the temperature-time curves in two consecutive cycles are identical. But still the problem is one of transient heat flow, because the temperature during a cycle changes with time.

For steady-state operation and properties independent of temperature the behavior of a counterflow heat exchanger can be described analytically by Equations 2-1 and 2-2[4], showing the gas and air exit temperatures as dependent on the various design parameters and the entrance temperatures. Equation 2-1 and 2-2 are developed in reference[4], pp 116 and 117.

$$T_{ge} = (T_{gi} - T_{ai}) \times \frac{1 - [(wc)_g/(wc)_a]}{e^{\left[\frac{U_0PL}{(wc)_g}\left(1 - \frac{(wc)_g}{(wc)_a}\right)\right]} - [(wc)_g/(wc)_a]} + T_{ai} \quad (2\text{-}1)$$

$$T_{ae} = [(wc)_g/(wc)_a](T_{gi} - T_{ai}) \times \left(1 - \frac{1 - [(wc)_g/(wc)_a]}{e^{\left[\frac{U_0PL}{(wc)_g}\left(1 - \frac{(wc)_g}{(wc)_a}\right)\right]} - [(wc)_g/(wc)_a]}\right) + T_{ai} \quad (2\text{-}2)$$

In the further text of this paper the word "heat exchanger" will always refer to a steady-state counterflow exchanger.

The regenerator study is carried out largely using dimensionless parameters; in order to maintain unity of presentation, the dimensionless values are introduced here.

$$K_1 = \frac{L}{y_0} \quad (2\text{-}3)$$

$$K_2 = \frac{1}{1 + (h_a/h_g)} = \frac{1}{1 + (K_5/K_6)} \quad (2\text{-}4)$$

$$K_3 = \frac{k_w L P}{(\rho cv)_g A y_0} \quad (2\text{-}5)$$

$$K_4 = \frac{k_w L P}{(\rho cv)_a A y_0} \quad (2\text{-}6)$$

$$K_5 = \frac{k_w}{h_g y_0} \quad (2\text{-}7)$$

$$K_6 = \frac{k_w}{h_a y_0} \quad (2\text{-}8)$$

$$K_7 = \frac{\alpha\tau}{y_0^2} \quad (2\text{-}9)$$

$$\theta = \frac{T - T_{ai}}{T_{gi} - T_{ai}} \quad (2\text{-}10)$$

Using these parameters, the heat exchanger equations presented in dimensionless form are:

$$\theta_{ge} = \frac{1 - (K_4/K_3)}{e^B - (K_4/K_3)} \quad (2\text{-}11)$$

for dimensionless gas exit temperature and:

$$\theta_{ae} = \frac{K_4}{K_3}\left[1 - \frac{1 - (K_4/K_3)}{e^B - (K_4/K_3)}\right] \quad (2\text{-}12)$$

for the dimensionless air exit temperature, where:

$$B = \frac{K_3[1 - (K_4/K_3)]}{K_5 + K_6} \quad (2\text{-}13)$$

If the wall conductance is included in the definition of U_0, as is the case in heat exchangers (as distinguished from regenerators) the denominator in Equation 2–13 becomes $K_5 + K_6 + 1$. In comparing a regenerator with a heat exchanger the area of the flue wall (perimeter × length) is comparable to the heat exchange area occurring in the heat exchanger; the item that is subject to change is the over-all heat transfer coefficient (U_0) and it is with this coefficient that one has to deal in trying to apply the simple heat exchanger equation to regenerators.

CONCEPT OF THE PROGRAM

Originally it was planned to compute the exit temperatures for a large number of regenerators by means

of the heat and mass flow analyzer and to plot the results in such a manner that interpolation would be possible. As work progressed it became obvious that correlation based on the heat exchanger equations with added corrections looked promising, while, in the light of the many variables, interpolation procedures using analog data would become very tedious.

Therefore, it was decided to base the calculation on the heat exchanger equation, as is usually recommended in most of the German literature on regenerators, where Hausen[1] has developed such factors to account for the cyclic behavior of regenerators. He, like all other investigators to date apparently, disregards heat conduction in the flue wall parallel to the direction of flow of the gases. Physical reasoning and exploratory computations on the heat and mass flow analyzer indicated that this conduction may not always be neglected. Therefore, an analytical equation for heat exchangers with longitudinal conduction was developed,[2] but since this equation is too involved for frequent engineering use, an approximate equation was also derived. Based on this work, corrections for longitudinal conduction were determined in the present study.

The whole question of accuracy and uncertainties, both in the light of assumptions made and of simplifications introduced for the sake of an easier procedure is discussed, the electric computing circuits which were used are described and a review of further work required is presented.

The computation of the correction factors and in part that of the heat transfer coefficient is straightforward but lengthy. In order to lighten the burden for the design engineer, a manual was developed, which permits a complete calculation to be performed, purely mechanically. The concept is that the engineer fills out the design data and then turns the calculation over to an aide, who need not have had engineering training. The simplified method of determining the gas radiative heat transfer coefficient is an approximation, but at the end of the manual there is an evaluation of the error introduced by this approximation.

In addition to this uncertainty the computational procedure involves a series of successive approximations; usually two or three trials only are needed. According to instruction the technician returns with the calculation to the design engineer, who decides whether additional trials are needed and whether the more precise but more complicated method for determining the radiative heat transfer coefficient described in the Appendix of the manual should be followed. This depends on whether the uncertainty in air exit temperature seems excessive.

The layout of the worksheets appended to the manual received special care, both with regard to the preciseness of instructions and simplicity and labor saving. In case of conflicting tendencies, simplicity was considered to be of greater importance than labor saving.

LENGTH CORRECTION

Usually in considering a heat exchanger the latter is thought of as having negligible heat conduction along the length of the separating wall. In order to proceed with the correlation of regenerators and heat exchangers, the equation describing the latter but including longitudinal conduction was developed. This development is primarily mathematical and is presented in a separate paper.[2]

The final expression for the exit temperatures is in the form of a third order determinant, in which the roots of a cubic equation are contained. To make it useful for the present purposes, an approximation was developed which is included in the above paper and which resulted in the following equations:

For the exit gas temperature ratio:

$$\theta_{ge} = \frac{1 - (K_4/K_3)}{e^{B_1} - (K_4/K_3)} \qquad (2\text{-}14)$$

and for the exit air temperature ratio:

$$\theta_{ae} = \frac{K_4}{K_3}\left[1 - \frac{1 - (K_4/K_3)}{e^{B_1} - (K_4/K_3)}\right] \qquad (2\text{-}15)$$

where B_1 is in magnitude the smaller root of a quadratic equation and is given by Equation 2-16 or Figure 7.

$$B_1 = \frac{(K_1^2K_6 + K_1^2K_5 + K_3K_4)}{2\,(K_4K_5 - K_3K_6)} \times$$

$$\left[1 - \left(1 - \frac{4\,K_1^2(K_3 - K_4)(K_4K_5 - K_3K_6)}{(K_1^2K_5 + K_1^2K_6 + K_3K_4)^2}\right)^{1/2}\right] = \frac{K_3(1-K_4/K_3)}{(K_5' + K_6')} \qquad (2\text{-}16)$$

Equations 2-14 and 2-15 should be compared with Equations 2-11 and 2-12 respectively, which hold for heat exchangers without longitudinal conduction. The only difference is in the exponents (replacing B, defined by Equation 2-13, with B_1, defined by Equation 2-16).

For the present purposes, both for heat exchangers and regenerators the Equations 2-14 to 2-16 may be used if:

$$\frac{K_1^2}{K_2} \geq 7.2 \qquad (2\text{-}17)$$

and

$$\frac{K_5 + K_6}{K_3} \geq 0.02 \qquad (2\text{-}18)$$

and as long as

$$0.002 \leq \frac{K_4}{K_3} \leq 35 \qquad (2\text{-}19)$$

and

$$0.001 \leq \frac{K_5}{K_3} \leq 1.0 \qquad (2\text{-}20)$$

It is quite possible that the limits of applicability are even larger than shown, but accuracy was explored within these limits.

HAUSEN'S TECHNIQUE—TIME CORRECTION

This technique is reported here as shown in the VDI-Waermeatlas,[3] but reference is also made to the original article by Hausen[1] and his book on heat exchangers and regenerators.[4]

While Hausen deals with the general case that the lengths of the gas and air periods are different, the following presentation is based on the common condition that they are equal.

The gas and air exit temperatures of a counterflow heat exchanger in steady-state can be computed from Equations 2-1 and 2-2, or, in dimensionless terms, from Equations 2-11 and 2-12. According to Hausen these equations can be used to determine the exit temperatures of gas and air in a regenerator, provided B is replaced by a fictitious one which includes a correction for the cyclic and transient behavior of a regenerator but no correction for the effect of length.

COMBINED LENGTH AND TIME CORRECTION

The manual follows Hausen's procedure for time correction except that the term, $K_5 + K_6$, has been replaced by $(K_5' + K_6')$. First one determines G_1 which is a function of $(1/K_7)$ as given by Figure 8; next two parameters are calculated.

$$G_3 = \frac{4}{[(1/K_3) + (1/K_4)][(K_5' + K_6') + G_1]} \qquad (2\text{-}21)$$

and

$$G_2 = \frac{2K_7}{(K_5' + K_6') + G_1} \qquad (2\text{-}22)$$

With these one finds G_4 from Figures 9 or 10.

Equation 2-23 gives the time-length corrected overall heat transfer coefficient in dimensionless form:

$$(K_5'' + K_6'') = \frac{(K_5' + K_6') + G_1}{G_4} \qquad (2\text{-}23)$$

HEAT TRANSFER COEFFICIENT

In regenerators, as in most heat exchangers, the heat transfer coefficient is the factor controlling the heat exchange. Therefore, available data were scrutinized. While the gas exchanges heat with the flue wall by radiation and convection, the heat transfer coefficient during the air period is due to convection only.

Convective heat transfer coefficients—Assuming uniform distribution of gas or air over all flues, regenerators operate mostly at fluid velocities near the critical Reynolds number. Many calculations both of heat exchangers and regenerators were carried out applying heat transfer coefficients based on frequently used equations.

For the laminar region Equation 2-24 developed by Hausen[5] and reprinted by Eckert[6] is;

$$\frac{hD}{k} = 3.65 + \frac{0.0668\ [(D^2v\ \rho c/kL]}{1 + 0.04\ [(D^2v\rho c/kL)]^{2/3}} \qquad (2\text{-}24)$$

For the turbulent region a correlation of data by several investigators is shown in Equation 9-10a of Refereance 7 on page 219. There the value of h refers to a point at some distance from the entrance where inlet disturbances are overcome. In order to account for these disturbances McAdams[7] gives a correlation $[1 + (D/L)^{0.7}]$ which is to be introduced in the aforementioned equation and leads to Equation 2-25;

$$\frac{h\ D}{k} = 0.023 \left(\frac{Dv\rho}{\mu}\right)^{0.8} \left(\frac{c\mu}{k}\right)^{0.4} \left[1 + \left(\frac{D}{L}\right)^{0.7}\right] \qquad (2\text{-}25)$$

For the transition region a correlation made by Krell is shown in McAdams.[7]

The heat transfer coefficient resulting from these equations leads to a computed performance of regenerators far lower than indicated by experience. A probable explanation for the failure of these otherwise well established relations is the difference in the nature of the flue wall and, possibly, the temperature range of observation. Equations 2-24 and 2-25 summarize a large number of experiments carried out in rather small metal tubes. In the regenerator the flue walls are large and made of brick.

Two German investigators, Kistner[8] and Boehm[9] have studied the heat transfer coefficient in regenerator flues; Kistner, working on a pilot plant regenerator, encountered greater difficulties in measuring both flow rates and temperatures than Boehm, who used a single experimental horizontal brick-lined flue. Kistner's correlation resulted in an equation which in British units reads:

$$h_c = 0.021 \frac{v}{(D)^{1/3}} \frac{\text{Btu}}{\text{sq ft, hr, F}} \qquad (2\text{-}26)$$

which is so contrary to other recognized relations (since temperature effects are disregarded) that further efforts were concentrated on Boehm's paper. His experimental flue was about 14-ft long. Flues of specific degrees of roughness (Figure 1) were investigated, but only two widths (3.4 and 1.8 in.) were used. Boehm worked with air having an entrance temperature of 1652 F.

For the laminar region he suggests an equation of the type:

$$h = T^{0.25}\left(a + b\frac{v}{D^e}\right) \qquad (2\text{-}27)$$

Boehm shows but two values of e: for smooth flues, type A, he quotes 0.4, for roughness, types D-E, Figure 1, a value of 0.6 is given; for other degrees of roughness no dependence on D is shown since only one flue width was investigated by him.

For the turbulent region Boehm's equation has the form

$$h = \frac{f\ v^{0.8}T^{0.25}}{D^{0.333}} \qquad (2\text{-}28)$$

Here f is different for different degrees of roughness. However, if evaluated for the critical Reynolds number, the laminar equation yields consistently higher values than the turbulent one. Therefore, Boehm says that one has to fair the data for the transition region. Boehm's Figure 12[9] shows this smoothing, but omits the information regarding the temperature. Also, contrary to his equations, the slope in the laminar region seems smaller than that in the turbulent one.

Boehm summarizes his findings in his Table I,[9] in which he shows for each of the several roughness types two equations for the turbulent regions and one for the laminar region. The latter equation and one for the turbulent regions are called "Equations as Determined," while the second "turbulent equation" is designated as "Recommended." Separately for each regime he presents a column "per cent increase above the smooth flue," indicating the ratio of h values. For

the turbulent region the information corresponds to the several values of f (Equation 2-28). But no such simple relationship exists, or for that matter can exist, for the laminar region if the latter can be described by an equation of the form of Equation 2-27.

The ratio of Boehm's roughness factors for the laminar to that of the turbulent regions are almost the same for the flues of roughness types A to E (Figure 1), the ratios varying from 1.21 to 1.29, but for roughness types F to I the ratios of roughness factors for laminar to turbulent regions are practically one. It has been found that Boehm's laminar equation for a roughness type H (Figure 1) yielded in a number of practical regenerator calculations reasonable results. Therefore, Figures 3a and 3b were based on Boehm's equations; in both figures h values at 1000 F are plotted against velocity; several curves are shown, holding for different flue sizes. Figure 3a holds for smooth brick flues, Figure 3b for flues of type H (Figure 1). Each of the two figures is composed of two sections, one for the laminar region, one for the turbulent one. Each curve was computed and plotted based on Equations 2-27 and 2-28 respectively and is extended to the point of intersection which in the case of Figure 3a is outside the figure. Frequently the point of intersection turns out to be far above the critical velocity. Since Boehm indicates both for the laminar and the turbulent region a variation of h with the 0.25 power of temperature, a separate figure, Figure 2, is presented for temperature correction.

It should be noted that contrary to accepted theory Boehm does not show any influence of the length of the flue on the heat transfer coefficient. Influence of length is commonly attributed to the fluid flow disturbances in the entrance region. It is quite possible that in the rough brick-lined flue the entrance region is relatively short and the influence of the total length therefore limited. But this and other shortcomings of Boehm's work should be explored further.

Radiative heat transfer coefficient—Some gases radiate and absorb heat; dry air does not. Therefore, for the gas cycle the heat transfer by radiation in addition to that by convection has to be considered. Of the gases present in the combustion products in high concentrations, only CO_2 and H_2O need be considered in connection with radiative heat transfer.

The heat exchange between an absorbing gas and a solid wall is described by Equation 2-29:[6]

$$Q = 0.173 \left[\epsilon_{gw} \left(\frac{\bar{T}_g}{100} \right)^4 - \epsilon_{gw} \left(\frac{\bar{T}_w}{100} \right)^4 \right] \quad (2\text{-}29)$$

The emissivity (ϵ_{gw}) representing an effective value depending on a number of factors reviewed below, cannot be put ahead of the bracket because it is temperature dependent.

The value of ϵ_{gw} depends on the emissivities of the several absorbing components of a gas mixture (e.g., CO_2, H_2O, etc.), the partial pressures of each component, the total pressure of the gas, the geometry of the arrangement and the emissivity of the brick.

The determination of ϵ_{gw} used in the Appendix of the manual follows essentially the procedure of Reference 3, p. Ka 7-Kc 1-4 with the following exception: the gas emissivity curves, including pressure correction, were taken from McAdams.[7]

The method indicated above can be carried out by following the procedure in the Appendix of the manual. But in view of its length and since the convective heat transfer coefficient during the air period is almost always the controlling factor, an approximate technique was developed, which is found in the manual.

This simplified technique is based on the heat transfer coefficient existing for the case of a "standard gas," considered to have a typical composition, namely, containing as the only radiating components 14 per cent CO_2 and 13 per cent H_2O. For this gas and a wall emissivity of 0.8, h_{gr} values were plotted as function of gas and wall temperatures and the hydraulic diameter, see Figure 6. Then similar curves were developed for a large number of other gas compositions and for wall emissivities between 0.75 and 0.85. The ratio of the values so found and those computed for the "standard gas" were plotted as correction factors (Figure 5); in order to simplify presentation, the influence of the wall emissivity was eliminated. This was achieved by always using that limit of emissivity leading to the highest correction factor. Figure 5 holds within certain limits given in the above-mentioned section of the manual. This procedure is justified since Figure 5 is indicated as approximate.

In order to find out whether the more accurate method of the Appendix must be used, a system of evaluating the uncertainty was developed on the following basis. Because of the predominant influence of the convective heat transfer coefficient, the percentage uncertainty ($U_{h_{gr}}$) in h_{gr} may be large, but result in only a small change in the air exit temperature. The relationship between the two uncertainties can be found by differentiating the expression of dimensionless air exit temperature with respect to h_{gr} as follows:

The dimensionless air exit temperature is

$$\theta_{ae} = \frac{K_4}{K_3} \left[1 - \frac{1 - (K_4/K_3)}{e^{F_2} - (K_4/K_3)} \right] \quad (2\text{-}30)$$

where

$$F_2 = \frac{K_3 - K_4}{(K_5'' + K_6'')} \quad (2\text{-}30a)$$

First differentiate θ_{ae} with respect to β:

$$\frac{d\theta_{ae}}{d\beta} = - \frac{K_4}{K_3} \left(1 - \frac{K_4}{K_3} \right)^2 \left[e^{F_2} - \frac{K_4}{K_3} \right]^{-2} \beta^{-2} e^{F_2} \quad (2\text{-}31)$$

where

$$\beta = \frac{(K_5'' + K_6'')}{K_2} = \frac{K_5 + K_6 + (K_3K_4/K_1^2) + G_1}{G_4K_3} \quad (2\text{-}32)$$

This holds if in Equation 18, B_3 is taken to be zero. Since h_{gr} appears in K_5 only:

$$\frac{d\beta}{dh_{gr}} = \frac{k_w}{G_4 K_3 y_0} \frac{d\beta}{dh_{gr}} [(h_{gr} + h_{gc})^{-1}] =$$

$$- \frac{K_5}{K_3} \frac{1}{G_4} \frac{1}{(h_{gr} + h_{gc})} \quad (2\text{-}33)$$

Then the change in θ_{ae} due to a change in h_{gr} is:

$$\frac{d\theta_{ae}}{dh_{gr}} = \left(\frac{d\theta_{ae}}{d\beta}\right)\left(\frac{d\beta}{dh_{gr}}\right) \approx \frac{\Delta\ \theta_{ae}}{\Delta\ h_{gr}} \qquad (2\text{-}34)$$

In the manual the ordinate F_3 in Figure 14 is equal to $\frac{d\theta_{ae}}{d\beta}$. Thus Equation 2-34 may be written:

$$\Delta\ \theta_{ae} \approx \Delta\ h_{gr}\ F_3 \left(\frac{d\beta}{dh_{gr}}\right) \qquad (2\text{-}35)$$

or, substituting Equation 2-33 into Equation 2-35 and expressing h_{gr} as the percentage uncertainty $U_{h_{gr}}$ yields the dimensionless change in air exit temperature

$$\Delta\ \theta_{ae} \approx -\ \frac{U_{h_{gr}}}{100}\ \frac{F_3}{G_4}\ \frac{K_5}{K_3}\ \frac{1}{[1 + (h_{gc}/h_{gr})]} \qquad (2\text{-}36)$$

Finally, in order to express the uncertainty in air exit temperature in degrees F, multiply $\Delta\ \theta_{ae}$ from Equation 2-36 by $(T_{gi} - T_{ai})$. The uncertainty expressed in degrees F is called $U_{T_{ae}}$ and may be found from Equation 2-37.

$$U_{T_{ae}} = \frac{U_{h_{gr}}\ F_3\ K_5\ (T_{gi} - T_{ai})}{100\ G_4 K_3\ [1 + (h_{gc}/h_{gr})]} \qquad (2\text{-}37)$$

The maximum deviation $U_{h_{gr}}$ when computing h_{gr} by the simplified method as compared to the "general method" was found as follows:

In the development of Figure 5, for each gas composition, h_{gr} was computed by the general method for four points selected for the most extreme combinations of the following variables:

brick emissivities	0.75, 0.85
gas temperatures	500 F to 2600 F
hydraulic diameter	0.250 to 0.833 ft

The ratios of h_{gr} for a gas composition within the listed range and for the standard composition, both computed using the general procedure, were expressed in per cent. Let h_c be the exact value of the radiative heat transfer coefficient for the selected composition and h_s that for the standard composition. For example, for H_2O = 20 per cent and CO_2 = 15 per cent, typical values of the ratio h_c to h_s were 1.20, 1.24, 1.23 and 1.31.

Defining C as the average of the extreme values of h_c/h_s, one may write:

$$h_{gr} = C\ h_s \pm \frac{U_{h_{gr}}}{100}$$

where $U_{h_{gr}}$ is the remaining uncertainty in h_{gr} expressed as a percentage.

In this example the widest spread (1.31 − 1.20) 100 = 11 per cent divided by two yields an uncertainty of $U_{h_{gr}}$ = 5.5 per cent; this value is plotted in Figure 15 for this gas composition as final uncertainty to be used in connection with the estimate of the uncertainty in air exit temperature (Equation 2-31).

PROCEDURE

Based on the considerations of the previous sections, the procedure for computing a regenerator is summarized here.

Starting from the total rates of gas and air flow, the rates and velocities per flue are to be determined. Then the heat transfer coefficients for air and gas periods are computed separately, the latter including the radiative and the convective components. Using these values, the seven characteristic dimensionless values are determined (Equations 2-3 to 2-9). The next step comprises introduction of the length correction. This correction results in a revised value for the sum ($K_5' + K_6'$). With the revised sum the "time correction" is to be introduced, which relates the regenerator to the heat exchanger. The time correction results in a further modification of ($K_5' + K_6'$) to ($K_5'' + K_6''$). With this finally revised value, the gas and air exit temperatures can be computed on the basis of the conventional heat exchanger theory.

In the determination of the heat transfer coefficients, mean wall, air and gas temperatures are used. Since these mean temperatures are not known at the beginning of the computation, a trial and error procedure is required; mean values are estimated; the exit temperatures are determined, and based on these the mean values are re-estimated. Wall, gas and air temperatures vary over the length of the flue and during each cycle; the required mean is a space-time mean. The graphs in the manual are based on the integral of the temperature-space expressions for the heat exchanger.

ACCURACY CONSIDERATIONS

Deviations of the actual performance of regenerators from that predicted by the present method can be attributed to four groups of causes:

1. Operational deficiencies.
2. Basic assumptions.
3. Uncertainty of physical properties and heat transfer coefficients.
4. Approximations in the procedure.

Operational deficiencies include primarily channeling, then fouling of the flues, and possibly variations of gas and/or air inlet temperatures. The significance of channeling is shown in the manual.

Basic assumptions include primarily the use of property values at mean temperatures and uniform roughness of the flue for gas and air flow, while fluids flowing in opposite directions experience different degrees of roughness. In addition the mass of gas and air in the flues was neglected. This assumption was verified by analog computation for the case where these masses would produce a maximum effect; comparison showed the effect to be negligible. Further, the radiation between different parts of the flue walls was not considered.

Physical properties and the heat transfer coefficients are not known accurately. Errors resulting from poor estimates can be found by computing regenerators assuming different values. This is shown in part in the examples. The heat transfer coefficient and especially its convective component is of great influence.

Approximations in the procedure include the substitution of the heat exchanger equation with length and time corrections for a true regenerator equation. It was also assumed that the length correction for heat exchangers may be applied to regenerators: this assump-

tion, underlying the present technique, appears validated by the very good correlation between results obtained by this technique with solutions of the regenerator equations by means of the heat and mass flow analyzer.

The following accuracy considerations deal only with approximations in the procedure. Since the analytical solution for the regenerator equation is not known, only a comparison with results obtained on the heat and mass flow analyzer was possible. The results were obtained on a circuit representing the exact regenerator equation in lumped form. Using the same basic assumptions as in the present computational methods, the analog results are afflicted with two sources of error: the analog uses a finite number of spatial lumps, while a perfect representation would require an infinite number; in addition there are instrument and equipment errors to contend with.

Thus, in comparing the two sets of results, one can only speak of deviations, but cannot definitely attribute an error to either the computational or the analog technique.

Also, in considering the deviations the development of the present study should be kept in mind. Originally it was planned to compute a large number of regenerators on the heat and mass flow analyzer and in order to provide for interpolation the limits for the several actual variables (length, mass rates of flow, etc.) were selected. This leads in part to extremes in the dimensionless factors. Such a procedure necessitates the combination of contradictory data, for example a very high mass rate of flow is combined with a very low heat transfer coefficient, a condition obviously not practical. Thus many of the cases which were investigated represent extremes, recognizable by almost no drop in gas temperature or an air exit temperature very near the value of the gas inlet temperature. In most cases reported correlation is excellent even at such extremes.

Attention should be drawn to the very marked significance which Boehm attaches to the roughness of the flue wall. According to Boehm a relatively quite small change in roughness changes the heat transfer coefficient appreciably.

Analog tests and computations for heat exchangers with longitudinal conduction—About 900 heat exchanger calculations were carried out on the heat and mass flow analyzer, roughly half of which referred to exchangers with longitudinal conduction. In the following, analog results for 28 cases are presented in which longitudinal conduction was most significant, characterized by the lower limits of K_1^2/K_3, and results are compared with values obtained from Equations 2-14 to 2-16. All cases presented in Table VII are for $K_1^2/K_3 = 7.2$; part A of the table includes cases for which $K_5/K_3 = 0.16$, while part B holds for $K_5/K_3 = 0.001$.

In Tables VIIA and VIIB the columns 1 and 2 show the two additional dimensionless groupings required to describe a heat exchanger. The next four columns (3–6) deal with gas exit temperatures, and the last four (7–10) with air exit temperatures. Both for gas and for air the analog and the calculated results are shown in dimensionless terms. Then there follows the dimensionless deviation (columns 5 and 9) given as the difference of columns 3 and 4 and of columns 7 and 8 respectively, disregarding the signs. The deviations in columns 6 and 10 are expressed in degrees F and found by multiplying the values of columns 5 and 9 by the difference of the gas and air entrance temperatures (2500 F).

The comparison shows deviations of less than 30 F (if $T_{gi} = 2600$) for all reasonable conditions, that is, for regenerators with dimensional design factors within the range specified below:

Flue size	$3\frac{1}{4}$ x $3\frac{1}{4}$ to $9\frac{1}{2}$ x $9\frac{1}{2}$ in.
Wall thickness	$1\frac{1}{2}$ to 3 in.
Length	8 to 20 ft
Wall material	Firebrick to silicon carbide
Gas velocity	600 to 10,000 ft per hr
Air velocity	300 to 9000 ft per hr
Reversal period	5 to 15 min
Gas heat transfer coefficient	3.0 to 12 Btu per sq ft, hr, F
Air heat transfer coefficient	0.9 to 3.0 Btu per sq ft, hr, F

Combining the extremes of these design factors leads to the limits of the dimensionless characteristic ratios shown in Equations 2-3 to 2-10 and to limits for K_7 from 0.06 to 20.

Because of the original intention to cover an unusually large range of values, many combinations of the dimensionless parameters given in Table VII can occur only if some of the values lie outside the specified range. Frequently the deviation even for these cases is less than 30 F. The cases showing deviations larger than 30 F are considered "unreasonable" regenerators; this term is explained hereafter, using one case as an example:

$$\frac{K_4}{K_3} = 16; \quad \frac{(K_5 + K_6)}{K_3} = 3.556; \quad \frac{K_1^2}{K_3} = 7.2; \quad \frac{K_5}{K_3} = 0.16$$

The limits of K_1 can be found by combining the extreme values of L and y_0:

$$K_1 = \frac{L}{y_0}\frac{8}{0.125} \leq K_1 \leq \frac{20}{0.0625} \qquad (a)$$

The limits of 0.0625 to 0.125 ft hold for y; but the difference between y and y_0 is sufficiently small, so that for the present purposes the limits of y may be used.

In round figures:

$$60 \leq K_1 \leq 300 \qquad (b)$$

The limits of K_3 determined by introducing extremes listed above for all variables are:

$$0.8 \leq K_3 \leq 3200 \qquad (c)$$

and the limits of K_4 are:

$$0.8 \leq K_4 \leq 8000 \qquad (d)$$

Under no circumstance are the charts and procedure valid if either K_3 or K_4 are outside these limits. However, since the ratio K_4/K_3 is subject to limits, for any ratio of K_4/K_3 the limits of K_4 or K_3 are smaller than shown in (c) and (d). For example, for $K_4/K_3 = 16$ the

value of K_3 cannot exceed 500; any larger value of K_3 would lead to $K_4 > 8000$.

Next one has to examine K_4; since for square cross section of the flue, $A = \frac{P^2}{16}$ and with $(\rho c)_g \approx 0.024$

$$K_4 = \frac{k_w L P}{A y_0 (\rho c v)_g} = \frac{k_w K_1 16}{v_g 0.024 P}$$

Since $K_1 = 60$, $K_4 = 8000$

$$\frac{k_w}{\rho v_g} = \frac{8000 \times 0.024}{16 \times 60} = 0.20$$

The highest value for k_w (for silicon carbide brick) is about 8, the lowest value for $P = 1.25$.
Hence,

$$v_{g\ maximum} = \frac{8}{1.25 \times 0.2} = 32 \text{ ft per hr}$$

This gas velocity is unreasonable for a regenerator.

Comparison of computed with analog results for regenerators—A large number of computations of regenerators were carried out on the heat and mass flow analyzer in order to compare results with those obtained by the computation described above. Properties were kept constant with regard to length and time. Table VIII shows a number of cases, giving both analog results and those obtained by the present method; the deviation is again shown in dimensionless terms and in degrees F, as in Tables VIIA and VIIB. The remarks made with regard to the "unreasonable" regenerator still hold. The term will here be explained using the case:

$$K_3 = 0.8; \quad \frac{K_4}{K_3} = 1; \quad \frac{K_5}{K_3} = 0.625; \quad \frac{(K_5 + K_6)}{K_3} = 1.875; \quad \frac{K_1^2}{K_3} = 4500; \quad K_7 = 20;$$

$$K_1 = \sqrt{0.8 \times 4500} = 60;$$

$L = K_1 y_0$ which can vary from 60×0.0625 to 60×0.125 and $= 3.75$ to 7.5 ft

Only the 7.5 length is practical. Therefore:

$$y_0 = 0.125 \text{ ft}$$

$$K_7 = \frac{k_w}{(c\rho)_w} \frac{\tau}{y_0^2}$$

$$\tau = (20 \times 0.125^2) \frac{(c\rho)_w}{k_w} = 0.313 \frac{(c\rho)_w}{k_w}$$

$c \approx 36$ for the refractory in question. Hence,

$$\tau = \frac{11.2}{k_w}$$

Even if $k_w = 8$ (for silicon carbide brick), the period would be more than 1 hr; the regenerator is "unreasonable."

COMPUTING CIRCUITS

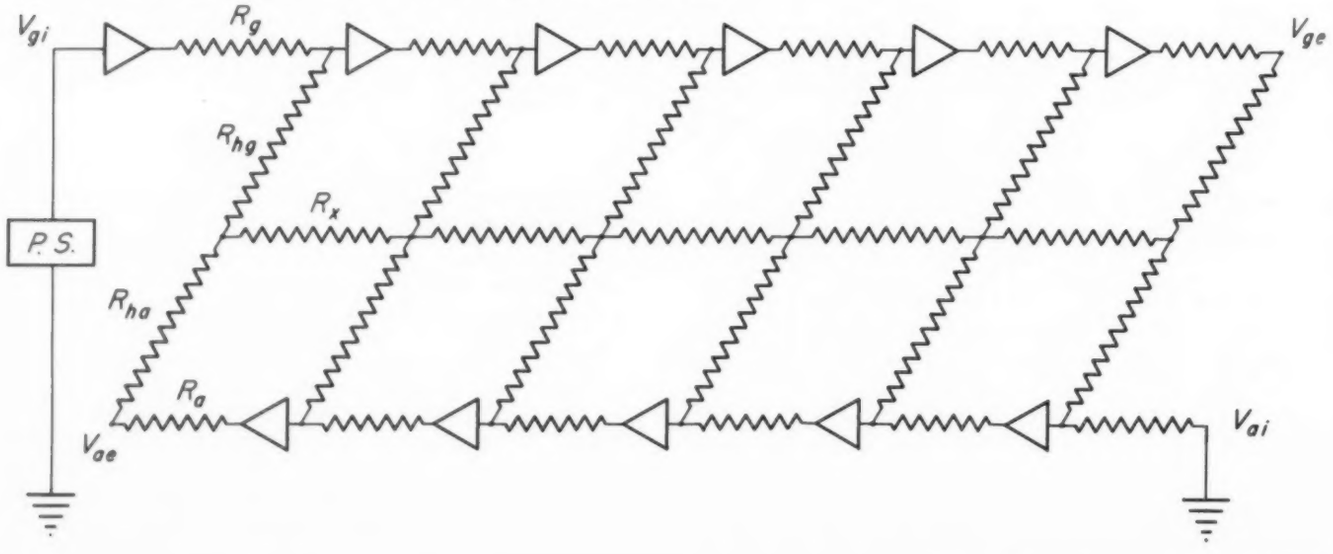
The heat and mass flow analyzer has been described repeatedly in literature and a full bibliography would be too long to include here but one can be obtained upon request from the third author, Dr. Victor Paschkis. The present brief review refers mainly to the special features relating to regenerators and heat exchangers.

Elements of analog computation—The heat and mass flow analyzer is a direct analog computer; generally voltages represent temperatures, currents are equivalent to rates of heat flow, electric capacities to heat capacity (specific heat × density) and electric resistors to thermal resistance. In heat exchangers and regenerators, resistors may also be used to represent the product of mass rates of flow and specific heat.

In designing computer circuits, a time scale can be introduced, so that the electric computations, say of happenings during a gas period, can be carried out in the same, a longer, or a shorter time than the gas period. For regenerators, one of two different computing circuits can be used.

Computing circuit for heat exchangers—The derivation of the circuit has been published previously.[10] The length of the heat exchanger is thought of as divided into a number of sections; in the study 15 were used, while Figure 23 shows such a circuit comprising

Figure 23—Computing circuit for a counter-flow heat exchanger.



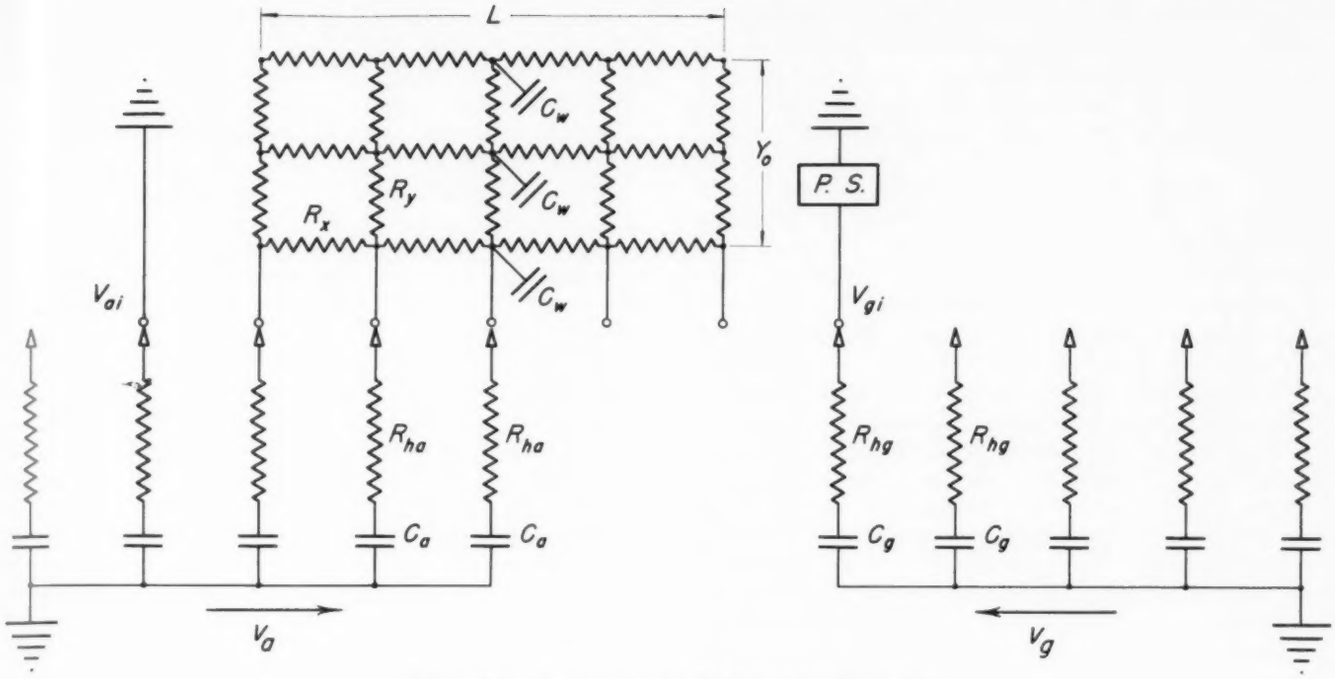


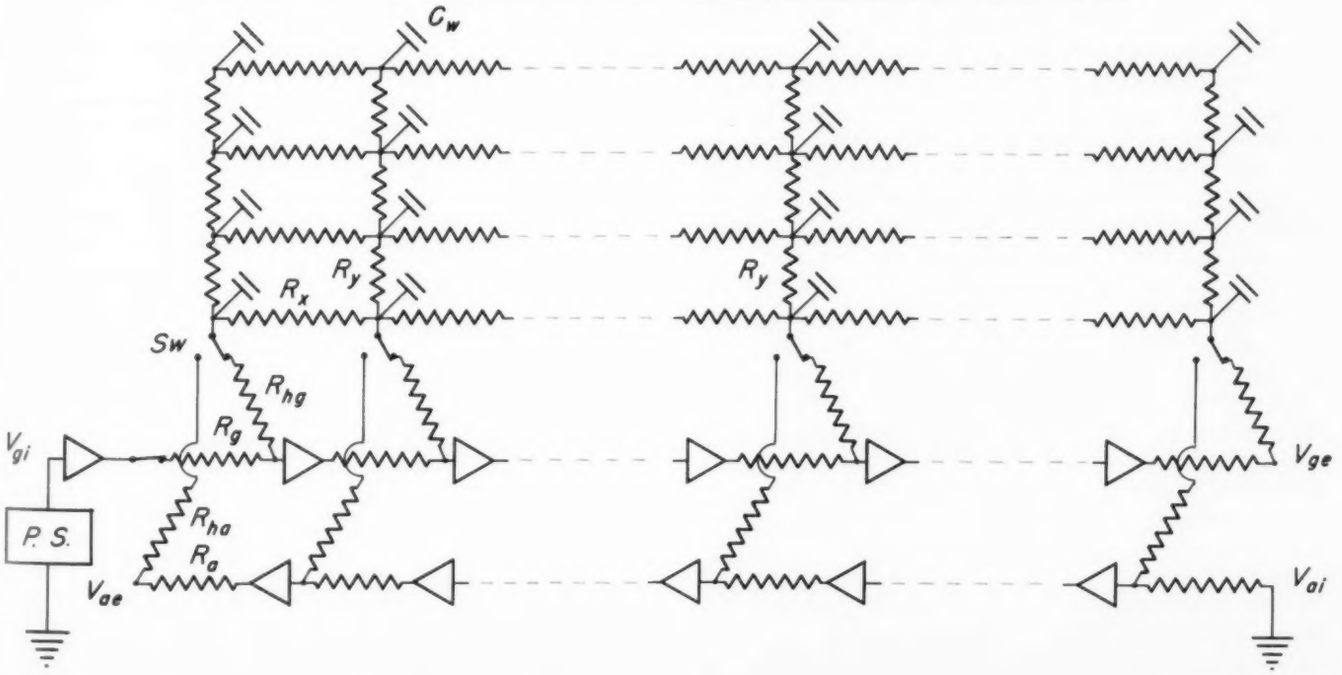
Figure 24 — Computing circuit for a regenerator.

six sections. Resistors R_h represent the resistance due to the heat transfer coefficients and due to the wall thickness; resistors R_h are subdivided into R_{h_g} and R_{h_a} for the hot and the cold side respectively. Resistors R_a and R_g represent the mass rates of flow (each multiplied by the respective specific heat) of the two fluids. The strings of resistors R_a and R_g are interrupted by unity gain cathode followers; these are devices having an output voltage equal to the input voltage and essentially an infinite input impedance and zero output impedance. This is required in order that all the heat given off in one section by the hotter fluid be absorbed by the colder fluid; the downstream element of fluid has no influence on the temperature of any upstream element.

At the center of R_h, i.e., where R_{h_g} and R_{h_a} meet, resistors are connected to represent the longitudinal heat conduction; for exchangers where this influence is disregarded, resistors R_x are omitted from the computing circuit. Voltages correspond to temperature differences, the entrance temperature of the colder fluid is taken as reference; currents represent rates of heat flow.

Computing circuits for regenerators (direct analogy)— By dividing the length of the flue into a number of sections and the length of the gas and air periods into a number of time steps, one can arrive at the network shown in Figure 24.

Figure 25 — Counter-flow heat exchanger computing circuit adapted for a regenerator.



Resistors R_x and R_y represent thermal resistances in the flue wall parallel and perpendicular to the direction of the fluid flow respectively.

A number of capacitances C_g are provided, each representing the heat storage capacity of the quantity of gas entering during the time element of the gas period. All these capacitances are precharged to a voltage V_{gi} corresponding to the gas inlet temperature. A second group of capacitances C_a are provided, each to represent the heat storage capacity of air entering during one element of the air period.

During the first time step one gas capacitor is connected to the first flue section across a boundary resistor R_{h_g}. At the end of the time step, the capacitor having lost some of its charge to the wall circuit (the gas having given off some of its heat to the wall) is connected to the second flue section, simultaneously, a second, freshly charged gas condenser is connected to the first section. At the end of the second time step both gas condensers are moved one step down the flue and a third enters. The procedure is continued to the end of the gas period. During the air period uncharged air condensers are moved in the same way but in the opposite direction. The voltage on the condensers indicates gas and air temperature respectively.

Regenerator studies with heat exchanger circuits—One can use a circuit very similar to the one used for the heat exchanger to study regenerators; it is this circuit which was used in the present study. The half-thickness of the flue wall was divided into four sections (Figure 25); each section is represented by two resistors (R_y for the resistance perpendicular to the flow direction of gas and air, R_x for the resistance parallel to that direction) and a capacitance C_w to represent the heat storage capacity.

FURTHER WORK

It is believed that the present paper represents an advance in regenerator design. In spite of the great effort made, much work remains to be done, which is listed in the sequence of importance except for channeling and the heat transfer coefficient which are felt to be of equal importance.

1. *Channeling*—The great influence of uneven distribution of gas and air, as shown in example eight, is proof, if one were needed, of the need for an investigation of channeling. Such an investigation should lead to a prediction of gas and air distribution. This work is to a large extent theoretical, of a similar nature, though in a different field, as the present work.

2. *Heat transfer coefficient*—The fact that the relatively crude values of Boehm seem to check better with practice than the established equations, shown by McAdams,[7] is indicative of the need for a determination of heat transfer coefficient values in bricklined channels. Work can be based on, but must by far exceed in scope and precision the efforts by Boehm. This problem lends itself best to experimental analysis in an industrial or university laboratory.

3. *Nonconstant properties*—All calculations to date were based on the assumption of constant properties. But all properties, particularly the heat transfer coefficients, vary from one end of the exchanger to the other. It is highly improbable that a general presentation with variable parameters is practical. But it is desirable to examine a number of characteristic cases to explore the influence of nonlinear parameters. This work can best be done on a computer.

4. *Fouling*—Deposits of dirt and slag change the cross section and the nature of the flue wall. While periodic cleaning is carried out, it appears desirable to get quantitative insight into the deterioration of the regenerator performance. Assuming thermal properties and amount of fouling, this work can be done by computation. Verification with plant experience is desirable.

5. *Deviations*—Deviation between analog results and those obtained by using the heat exchanger equation with corrections was discussed. The few cases where larger deviations occurred could be explored to find whether in that extreme region of parameter values the heat exchanger approach is less accurate or whether the heat and mass flow analyzer was at fault.

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Discussion

PRESENTED BY

T. R. SCHUERGER, Supervising Technologist, Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

Dr. V. PASCHKIS, Professor, Mechanical Engineering and Director, Heat and Mass Flow Analyzer Laboratory, Columbia University, New York, N. Y.

D. W. KERN, Engineer, Process Metallurgy Div., Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

T. R. Schuerger: I wish to suggest that as a further extension of this present regenerator work, the calculations that have been reduced to arithmetic, engineering calculations might also be done on the same digital computers the accounting and payroll departments are using. These machines are developed specifically to do arithmetic, and there is no need for engineering departments to burden either themselves or their technicians with calculations of a purely arithmetic nature. We are all aware of the fact that this presupposes that our engineering problem can be reduced to arithmetic.

Dr. V. Paschkis: In light of the rapid development of all types of computers and the keen competition between the several fields, I do not think that one can say in general that a specific problem can be solved better by one type of computer than by another. However, we find that the direct analog has one basic advantage for the practicing engineer. This advantage might be called "visualization." If one is facing a computer of this type, one can put one's hand on a piece of equipment and say that this capacitor represents the specific heat of a certain part of the equipment, i.e., the brick, and that this resistor represents the thermal resistance to heat flow in a specific part of the equipment. On the other hand it is obvious that the operations involving mainly arithmetic are well suited for the digital computer.

T. R. Schuerger: Our laboratory is doing regenerative heat exchanger work at present on an analog computer, so we are all thinking along the same lines. I wish to suggest that it is no longer necessary for us to burden ourselves with routine arithmetic work where digital computation facilities are available. Our laboratory has plans to do the theoretical work on an analog computer where the actual regenerator parameters can be readily studied in the time domain. When these theories are developed and verified, we then visualize programming the calculations for digital computers for engineering use. There is no argument about the utility of either digital or analog computers. They both have complementary functions.

D. W. Kern: In the past few years the Bethlehem Steel Co. research dept. has investigated the flow distribution of combustion air and waste gas in the regenerative system, both on operating open hearth furnaces and on a model furnace. More recently, a similar survey of combustion air and waste gas temperatures has been made. These studies have provided data which we have used to make a direct comparison of measured temperatures against corresponding calculated temperatures using the computing method outlined in the paper by Hlinka, Puhr and Paschkis.

The measurements and calculations were made on a two-pass regenerator, considering each pass separately. The combustion air and waste gas temperatures at the inlet of each flue in each chamber has been assumed to be equal to the temperature at the entrance to the chamber.

We were not able to determine exactly the effect of the idle pass on combustion air and waste gas temperature, because the hydraulic diameter for the idle pass flues is well beyond the range for the simplified method of calculation described by the authors. Even though the more detailed general procedure, shown in the Appendix, could have been used for determining the radiant heat transfer coefficient, the auxiliary factor F_1, which is necessary for the calculation of the convective heat transfer coefficient, cannot be determined except by rough approximation from Figure 3b of the paper. Therefore, in making this comparison, the combustion air temperature at the base of the hot pass is assumed to be 1000 F; this represents a 200 F increase in temperature contributed by the idle pass.

Both the hot and cold passes have been divided into three sections as shown in Figures 26 and 27. The flow distribution of combustion air and waste gas is shown schematically through each of the three sections in both the hot and cold pass.

All measured and calculated combustion air and waste gas temperatures are shown in their respective locations in Figures 26 and 27. The measured combustion air temperature at the exit of the cold pass is 800 F compared to a calculated temperature of 721 F; the measured combustion air temperature at the exit of the hot pass is 1270 F compared to a calculated temperature of 1301 F.

No comparison of measured and calculated waste gas temperatures is offered because physical limitations would not allow the measurement of waste gas temperature at the outlets of the hot and cold passes. Although there is no confirmation of the calculated waste gas temperature, the results, 2192 F at the exit from the hot pass and 1564 F at the exit from the cold pass, appear consistent with expected temperatures at these locations.

The method proposed by Hlinka, Puhr and Paschkis offers a simple, straightforward approach for predicting regenerator changes. The method can be easily followed and the calculations can be made by clerical or technician grade personnel with limited supervision once they have been supplied with the preliminary data.

It is felt that this method can also be used quite successfully in combination with model work on distribution of combustion air and waste gases in regenerators to provide a more comprehensive and practical approach to changes in regenerator design.

Equation 20 shows the length correction for the special case of $K_4 = K_3$, yet the correction factor does not appear to be dependent on length. What is the explanation?

Dr. V. Paschkis: In reply to Mr. Kern's question regarding Equation 20, I would like to refer to Equation 2-11, which shows the gas exit temperature, presented in dimensionless terms. If $K_4/K_3 = 1$, this equation becomes indeterminate, since both numerator and denominator would equal 0. To solve such an equation, numerator and denominator are differentiated inde-

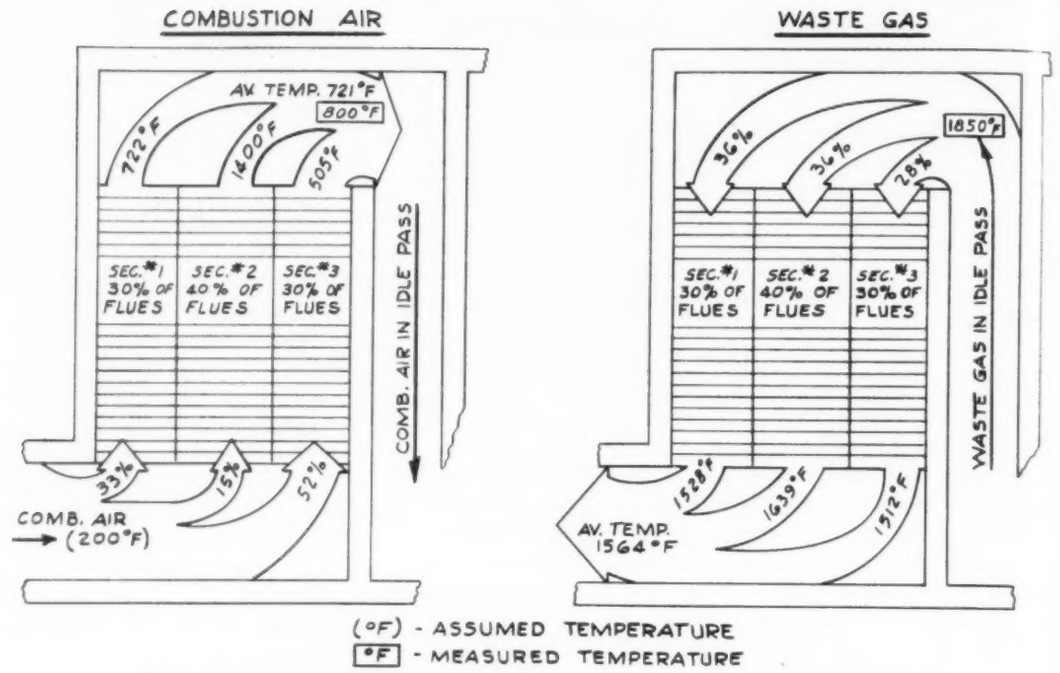

Figure 26 — Temperature and flow distribution in cold pass of regenerator.

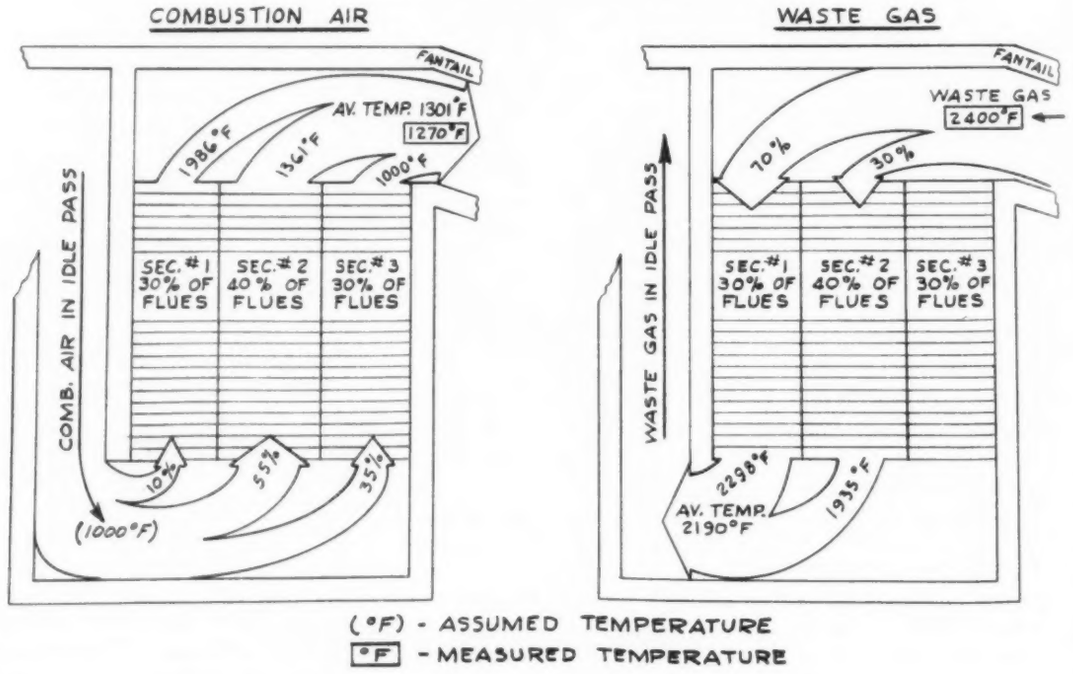

Figure 27 — Temperature and flow distribution in hot pass of regenerator.

pendently, and one arrives at the following equation

$$\theta_{ge} = \frac{1}{[K_3/(K_5 + K_6)] + 1} = \frac{K_5 + K_6}{K_3 + (K_5 + K_6)}$$

If a length correction is applied, the sum $(K_5 + K_6)$ is to be replaced by $(K_5 + K_6) + (K_3/K_1)^2$. Thus the expression for θ_{ge} becomes:

$$\theta_{ge}' = \frac{(K_5 + K_6) + (K_3/K_1)^2}{K_3 + [(K_5 + K_6) + (K_3/K_1)^2]}$$

In order to indicate that this equation holds with a length correction, θ_{ge} is written with a prime.

Now, in order to find out whether the length correction, as it would appear superficially from Equation 20, is independent of length, divide the equation for θ_{ge}' by the equation for θ_{ge} and note that K_5 and K_6 are independent of length.

$$\frac{\theta_{ge}'}{\theta_{ge}} = \frac{(K_5 + K_6) + (K_3/K_1)^2}{(K_5 + K_6)} \times$$

$$\frac{K_3 + (K_5 + K_6)}{K_3 + (K_5 + K_6) + (K_3/K_1)^2} =$$

$$\frac{(K_5 + K_6) + (K_3/K_1)^2}{(K_5 + K_6)} \times$$

$$\frac{1}{1 + (K_3/K_1)^2\,[1/K_3 + (K_5 + K_6)]}$$

From this equation one can see that since K_3 includes length, the ratio of temperatures with and without length corrections is not independent of the length of the regenerator and thus the length correction itself is also a function of the length.

In conclusion I would like to say that our laboratory would be happy to receive information on measurements on regenerators; if we receive sufficient information along that line, we can compare predictions made on the basis of our manual with actual performance and publish such a comparison. ▲

Automatic Gage Control On Reversing Cold Strip Mills

by ALONZO F. KENYON, Advisory Engineer,
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. . . . though hot strip mill finishing trains and tandem cold mills have received the benefits of the majority of automatic gage control applications in the past, the experience gained on these mills has been applied to systems recently put into operation on, and presently being designed for, single-stand, reversing cold mills . . . . accuracy of product gage promises to be equal to that rolled on tandem cold mills. . . . .

GROWING demands for maintained product uniformity and accuracy dictate the necessity for automatic gage control on all types of modern metal strip rolling mills. Installations have been made on both steel and aluminum continuous hot strip mills, aluminum strip and foil and other nonferrous metal cold rolling mills and both multi-stand and single-stand cold reduction steel strip mills.

The gage control systems for these various types of hot and cold mills all have some problems in common, so that the knowledge gleaned from analytical studies and operating experience with one type of mill is useful in planning the system for some other mill. However, every application presents new problems and unique combinations of operating conditions to be met. Therefore, each gage control system must be specifically designed to best meet the range of requirements, to make use of newly developed techniques and equipment components and to progress from the experience gained from earlier installations. On every job, the maximum benefits from the automatic gage control will be achieved only after careful and detailed consideration and analysis of all factors effecting the mill operation, and by proper coordination of the gage regulator with the mill screwdowns, tension regulators and mill and reel main drives. Even on the same type and apparently similar mills, the system to enable successful gage control will depend upon the metallurgical analysis and physical characteristics of the strip, thickness of strip, range of threading and running speeds, operating tension, permitted tension variation, etc.

This article describes in some detail two single-stand reversing cold reduction mills recently completed and put into operation, and the automatic gage control regulating systems supplied with these two mills to achieve accurate gage uniformity under somewhat different operating conditions. Note is also made of other gage control systems in the process of design and manufacture.

THE 42-IN. SINGLE-STAND REVERSING MILL

The 42-in. wide, single-stand reversing cold mill, put into operation at a Pittsburgh district plant during the summer of 1959, consists of a single, 4-high 16 and 49 x 42-in. roll stand, a heavy tension main reel on each side of the mill stand and an auxiliary entry pay-off reel. During the first pass strip is unwound from the coil on the auxiliary pay-off reel, passed through the mill and wound under tension on the delivery side reel. The tail end of the strip then is started on the entry side main reel, and on the second and succeeding passes, the strip is unwound from one main reel, passed through the mill and rewound on the other main reel. This reversible process continues for as many passes as necessary to reduce the strip to final thickness.

This 42-in. mill was intended primarily for the cold reduction of grain oriented electrical steel strip and other similar silicon alloy steel strip. These silicon steel alloys work harden quite rapidly during cold

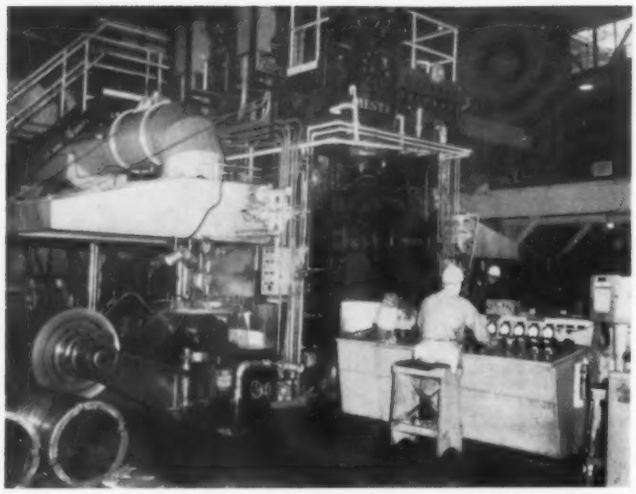


Figure 1 — The 42-in. mill is powered by a 5500-hp motor.

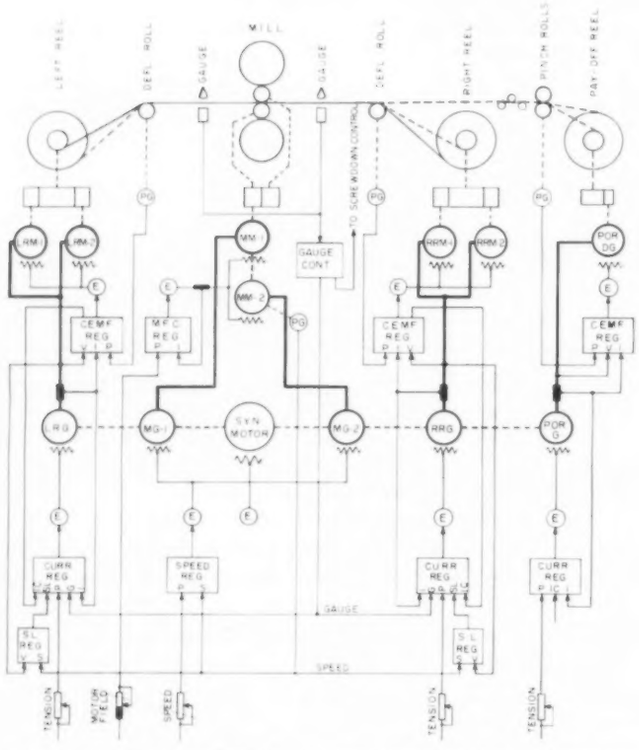


Figure 2 — The two 2200-kw generators and the mill motors are connected in a sandwich-series circuit.

rolling, and usually require intermediate annealing and two rolling programs to produce the required final strip thickness. In the first rolling operation, pickled hot rolled strip 0.070 to 0.090 in. thick is reduced to 0.018 to 0.028 in. thick in three passes. During this initial breakdown or rough rolling, the strip is wound directly on the reel mandrels.

After annealing and side trimming, the 0.018 to 0.028-in. thick strip is reduced to 0.009 to 0.014 final thickness in the second or finish rolling operation. On the first loading pass the strip is unwound from the coil on the auxiliary pay-off reel, passed through the mill without any reduction and rewound. The second and third working passes effect reductions of 20 to 35 per cent per pass. On all passes of the finish rolling, the strip is wound on 2-in. thick sleeves.

In some cases the initial breakdown rolling is done on an adjacent 4-stand tandem mill, and only the finish rolling is done on the 42-in. reversing mill. In other cases both the initial breakdown rolling and the finish rolling operations are accomplished on the 42-in. reversing mill.

Figure 1 is a view of the mill from the delivery side, showing strip winding on the left reel, and also showing one of the floor-mounted master control benchboards and the coil sleeves on which the thin finished strip is wound.

Drive arrangement—Figure 2 shows the pass line elevation arrangement of the mill, and the simplified schematic connections of the mill and reel main drives. The mill work rolls are driven together through a pinion stand by the direct-connected 5500-hp, 250/490-rpm, 750-volt, double-armature motor, to provide mill speed range of 1050/2060 fpm with 16-in. nominal diameter work rolls. This is believed to be the most power ever applied to a single-stand reversing cold reduction mill. Power for the mill motor is supplied from two 2200-kw generators, and the two motor armatures and the two generators are connected in a sandwich-series circuit.

Each of the main tension reels is driven by two 700-hp, 200/800-rpm, 600-volt motors, supplied together from an 1150-kw generator. Each reel drive consists of two single-armature, 2-bearing motors, arranged side-by-side on 72-in. horizontal centers and driving into the two pinions of a special gear reducer, rather than the more usual double-armature motor connected to the reel through a conventional gear reducer. The reel motors are installed immediately adjacent to the gear drives, outside the motor room.

The auxiliary pay-off reel drives a 100-kw drag generator, and the regenerated output is absorbed by a 100-kw generator (motor) on the main motor-generator set. On some mills, the pay-off reel feeds strip to the mill only on the first pass which normally is made at moderate speed and quite heavy reduction, so that the pay-off reel need operate only at quite slow speed. However, on this mill, the pay-off reel feeds strip to the mill on a loading pass which is made at maximum speed and without any reduction, so that the pay-off reel is geared to run up to the maximum rated mill speed.

Mill and reel regulators—All main drive motors and supply generators are excited by quick-response forcing exciters, and the exciters are controlled by 60-cycle magnetic amplifier regulators.

The 5500-hp mill drive regulating system includes features to assure accurately maintained, stable threading and running speeds, and uniform straight-line acceleration and deceleration throughout the speed range. The mill speed is made to accurately follow the travel of the master rheostat, by means of a speed regulator which controls the supply generators over the entire range from threading to maximum running speed, supplemented by the mill-rotor field-current regulator controlled from a second plate on the master rheostat to assure the required motor field currents for weakened field speeds.

The tension regulating system for each reel consists of a magnetic cemf regulator controlling the reel motor to maintain the reel circuit counter voltage proportional to the strip speed, and a current regulator controlling

TABLE I
The 42-In. Reversing Cold Reduction Mill

Mill data	
Working rolls	16-in. diameter by 42-in. face
Backing rolls	49-in. diameter by 42-in. face
Mill motor	5500-hp, double armature, 250/490-rpm, 750-volt
Drive	Direct to pinions and work rolls
Nominal mill speed, fpm	1050/2060
Width of strip to be rolled, in.	30 to 37
Screw-down data	
Mill screws	18-in. diameter, 1/2-in. pitch
Screw-down motors	Two 50-hp, 550 to 1100 rpm, frame 610 special compound with constant-voltage magnetic control
Total gear ratio	1138.5 to 1
Screw speed	0.00044 in. per motor revolution, 0.242 to 0.484 in. per min
Entry and Delivery Main Reels Data	
Diameter of:	
Reel mandrel, in.	20
Coil sleeve, in.	24
Largest coil, in.	72
Maximum strip delivery speed, fpm	2120
Reel gear ratio	1.904 to 1
Motors, each reel	Two 700-hp, 200/800-rpm, 600-volt
Rated full load winding reel tension capacity, lb	21,000
Rated full load unwinding reel back tension capacity, lb	26,750
Range of tension adjustment, per cent	25 to 125
Auxiliary entry pay-off reel data	
Maximum nominal strip entry speed, fpm	2000
Pay-off reel gear ratio	3.04 to 1
Pay-off reel drag generator	100-kw, 300/1200-rpm, 250-volt
Rated full load pay-off reel back tension capacity, lb	2530
Range of tension adjustment, lb	1000 to 3000
General data	
Distance from mill center line to:	
Auxiliary entry pay-off reel	25 ft-6 in.
Right main reel	13 ft-0 in.
Right X-ray thickness gage	5 ft-11 in.
Left X-ray thickness gage	5 ft-11 in.
Left main reel	13 ft-0 in.
Power supply motor-generator set	
Mill generators—Two 2200-kw, 750-volt, 514-rpm, separately excited from forcing exciter and magnetic amplifier speed regulator, connected to 5500-hp, double-armature motor in sandwich-series loop.	
Left reel generator—1150-kw, 600-volt, 514-rpm, separately excited from forcing exciter and magnetic amplifier current regulator, supplying two 700-hp motors in parallel.	
Right reel generator—same as for left reel.	
Auxiliary pay-off reel generator (motor)—100-kw, 250-volt, 514-rpm, absorbing regenerated output from 100-kw drag generator.	
Synchronous driving motor—8000-hp, 0.9 power factor, 200 per cent pullout torque, 6900-volt, 3-phase, 60-cycle, 14-pole, 514-rpm with neutral reactor starting and bearing oil lift pumps.	

the supply generator to maintain the set current in the armature circuit. The pattern signals for the cemf regulators are derived from pilot generators driven from the strip, hence the regulators are directly responsive to the strip speed and require no manual compensation for mill roll diameter, mill reduction, extrusion effect, etc., as is necessary where the reel pattern signals are derived from a pilot generator on the mill motor. Auxiliary speed limit regulators are provided for the two main reels to limit the reel speed in case of a strip break during normal operation at running speed. Reel inertia compensation is made responsive to the strip width, coil diameter and acceleration rate.

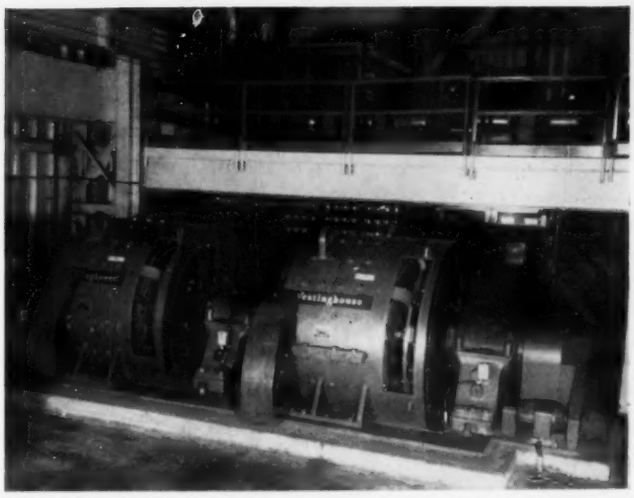


Figure 3 — The motor room layout was made compact by installing a substantial amount of equipment on a balcony.

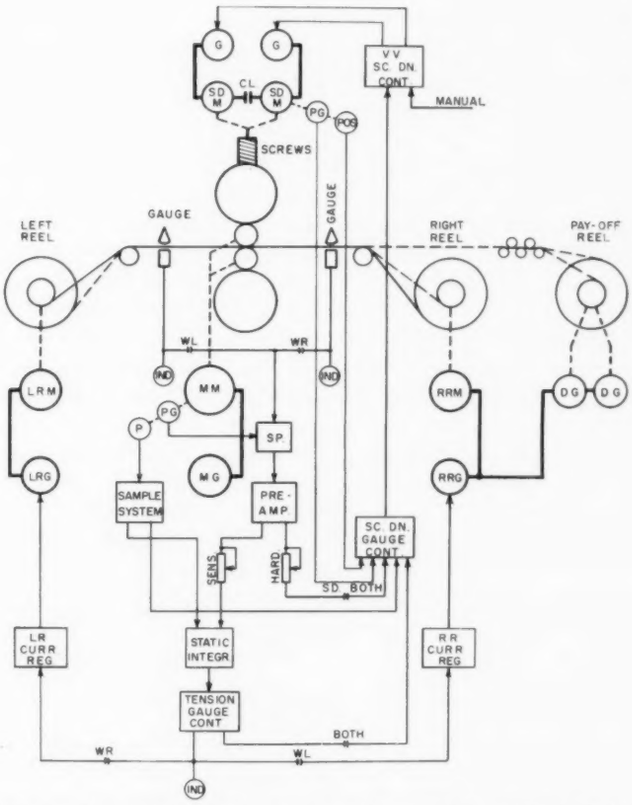


Figure 4 — Two X-ray gages are used to measure strip thickness deviation. The gage used depends upon the direction of rolling.

Mill data—Table I lists pertinent data regarding the mill, main and auxiliary pay-off reels, screwdowns and the electrical drive equipment.

The 5500-hp, double-armature mill drive motor is shown in Figure 3. A very compact motor room arrangement is achieved by installing the exciter sets, motor-operated rheostats and constant-voltage auxiliary control panels, on a balcony, and installing the main-drive duplex control board and the gage control equipment under the balcony at the end of the motor room. The ventilation system air cleaner and fans are installed on the motor room roof.

Automatic gage control—Figure 4 is a schematic mill arrangement and simplified block diagram of the automatic gage control system as applied to this 42-in. reversing cold mill.

Since this is a reversing mill, there are provided two X-ray strip thickness gages to enable measurement of the delivered strip thickness when operating either from right to left (odd-numbered passes) or from left to right (even-numbered passes). Relays WL and WR operate from the mill directional control so that the strip thickness deviation input signal to the gage control always comes from the gage at the exit side of the mill. The gage control is responsive to the deviation from the set delivered strip thickness on each pass in alternately opposite directions of rolling. Each of the gages is located 5 ft-11 in. from the mill centerline.

Selector switches are provided on the master control benchboards by which the mill operator may select to regulate the delivered strip thickness by: (1) controlling only the strip back tension; (2) controlling only the screw position; or (3) controlling both the strip back tension and the screw position. On this mill it has been found that best over-all operation is obtained by having the gage regulator control both the strip back tension and the screw position. Most of the following description will be on the basis of the combination tension and screw-down mode of gage control operation.

Screwdown—The mill screws are 18-in. diameter and ½-in. pitch screws, driven through a 1138.5 to 1 total gear ratio by two 50-hp, 550/1100-rpm, 230-volt, 610 special compound-wound motors. With this screw-down drive, each 0.001 in. of screw movement corresponds to 2.28 motor revolutions, and the 550/1100-rpm motor speed corresponds to 0.242/0.484-in. per min screw speed. The screw-down motors are operated from the 250-volt, constant-voltage, d-c shop supply; however, the constant-voltage magnetic controller was specially designed to eliminate or reduce time delays and thus assure quick response in making corrective screw-down movements. In the normal off position, the clutch between the motors is normally energized and engaged, the negative line contactor is closed and the dynamic braking contactor is opened. The picking up of a single control relay in the gage control initiates the screw-down operation. Accelerating relays are adjusted to obtain the fastest practicable acceleration. Oscillograph tests show that the screw-down motors are moving within 0.2 sec after an initiating error or deviation signal from the X-ray gage. The screw-down motors are totally enclosed and nonventilated. Operations are not so frequent as to cause excessive motor heating.

Operation of gage control—The operation of the automatic gage control system is essentially as follows: a speed signal from the mill pilot generator connects and permits the gage control to function only when the mill is running above about 200 to 300 fpm. A preamplifier raises the strip thickness error signal from the exit side X-ray gage to a convenient power level, and this amplified error signal is fed through a servo-integrator to the tension gage control regulator. The servo-integrator normally operates at slow speed with low gain, is effective continuously and operates on all errors with practically no dead band, thus achieving maximum steady state accuracy without instability. However, if the error increases rapidly to 0.25 mil or more, the integrator gain is increased for a short jog time to correct the gage quickly by tension. The sampling system permits the integrator to operate for a measured on time at the fast high-gain rate proportional to the error, then does not permit another fast operation until after an off time for the gage, to see the result of the preceding fast corrective tension change. This enables fast corrective tension changes essentially proportional to the thickness errors without danger of instability.

As shown by the block diagram in Figure 4, the output from the tension gage control is fed through WL or WR contacts to the unwinding side reel current regulator to control the strip thickness by changing the back tension. It has been observed that on the usual light gage silicon steel strip the delivered thickness can be corrected on the order of 0.075 to 0.15 mil per 100-amp change in unwinding reel current. Also, it has been found undesirable to change the unwinding reel current over a range of more than about plus or minus 250 amp from the value set by the manual tension adjusting rheostat. Thus the gage correction which can be obtained by tension control is relatively small, and any deviations greater than about 0.19 to 0.38 mil must be connected by screw-down operation.

When operating in the combination tension and screw-down mode of gage control, the screws are permitted to jog only when the tension correction approaches 200 amp. The amplified thickness deviation signal also is fed to the "screws jog" gage control. Whenever the deviation exceeds the dead band (adjustable for either 0.25 or 0.50 mil), the screws jog for a selected on time. The screws jog control provides two on times of about 0.8 and 1.8 sec, and the screw-down motors are operated for the short time when the gage error is small at the time the jog operation is initiated, and for the long time when the initiating error signal is large. The screw movement required to correct any gage error is always much larger than the error, due to the spring of the mill, and varies with the hardness of the strip being rolled. Therefore, a hardness switch is provided to enable more nearly matching the corrective screw movement to the initiating error signal.

After each corrective screw jog operation the sample system prevents another screw jog operation until after an off time sufficient for the strip to travel from the roll bite to the X-ray gage, so the gage can see the result of the preceding corrective screw movement.

When operating in the screw-down only mode, the tension limit permissive circuit to the screws jog control is ineffective and the screws jog whenever the thickness deviation exceeds the dead-band setting.

The allowable range of back tension variation enables gage control only over a rather limited range of thickness deviation; therefore, the tension only mode of operation has limited use. The screw-down only mode of operation has been found quite satisfactory in maintaining good gage uniformity, but necessitates quite frequent screws jog operation. The tension control provides very effective gage control within its limited range of correction, and the combination tension and screw-down mode of operation provides better control over an extended range and reduces the number of screws jog operations to about one fifth or one fourth the number of jogs when operating with screwdown

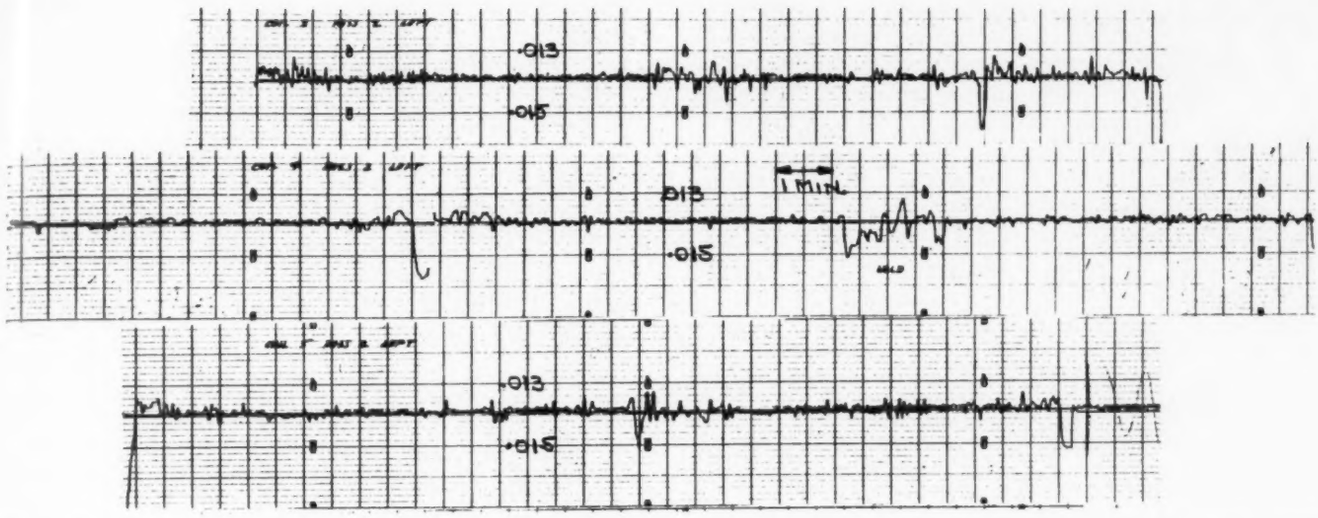


Figure 5 — Finish gage total deviation is held within desired limits except during starting and stopping of the mill and slow-downs necessary for the welds.

only. The continuously operating low-gain servo-integrator tension control provides maximum steady state accuracy as it operates with practically no dead band, and the high-gain sampling servo-integrator tesnsion control operates with a small dead band and with fast response to make corrections within the tension control range without initiating a screw-down operation, while corrections beyond the tension control range are made by either a small or large screws jog movement depending upon the error at the time the jog is initiated.

Figure 5 shows a section of strip thickness chart taken during the second finish rolling pass when reducing 0.018-in. thick nominal entering the strip to 0.014-in. finished gage silicon steel. Except during starting and when slowing down for welds, the gage control holds the total deviation to less than 0.2 mil and the average gage is held almost perfectly. Figure 6 is the front installation view of the 42-in. mill gage control equipment. The bottom panel includes the setup relays and the motor-operated servo-integrator. The panel immediately above it is the driver for the servo-integrator. The next two panels are the first stage preamplifier and the second stage tension gage regulator. The top panel includes the modules for the sampling system counters and long and short screws jog control.

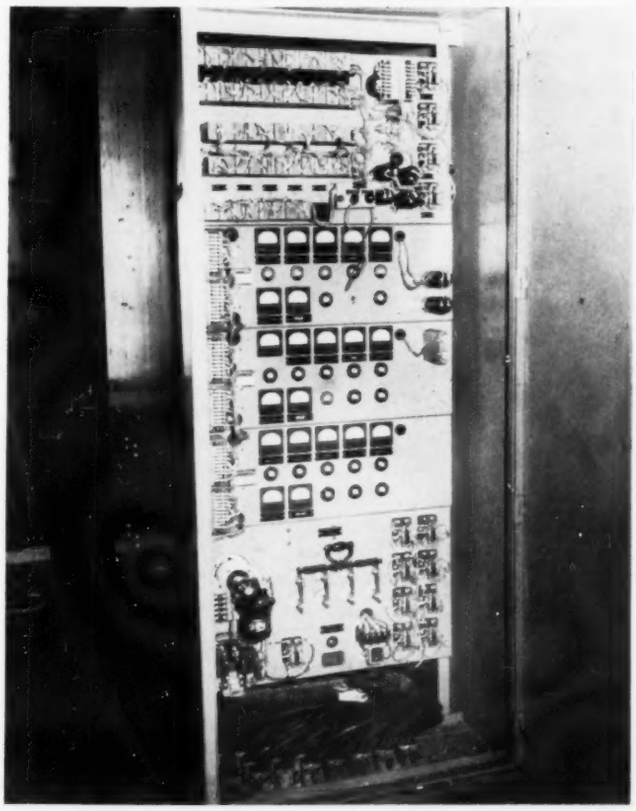
THE 56-IN. SINGLE-STAND REVERSING MILL

Another single-stand reversing cold reduction mill with a modern combination tension and screw-down automatic gage control, is the 56-in. mill put into operation (in early 1960) at a central Ohio plant. This anti-friction bearing equipped mill consists of a single 4-high, 18 and 51 x 56-in. roll stand, a heavy-tension main reel on each side of the mill stand, and an auxiliary entry pay-off reel. The mill operates at up to 1700 fpm maximum nominal speed.

This 56-in. mill will be used primarily for the cold reduction of low-carbon mild steel; however, it also will roll some stainless and other alloy steel and some silicon electrical steel. Also, in addition to the normal cold reduction operation, the control is set up to enable operation as a temper pass mill. Some stainless and other alloy steels work harden quite rapidly and may require intermediate annealing and pickling, thus requiring two or more mill rolling programs to reduce to the final strip thickness, while the usual reduction of low carbon mild steel may be completed in one cold rolling program.

The starting hot strip may be from 24 to 50 in. wide and from 0.075 to 0.250 in. thick, and the finished strip may be from 0.005 to 0.075 in. thick. On low-carbon

Figure 6 — The gage control equipment for the 42-in. mill uses modularized circuits for certain applications.



mild steel the mill may make reductions of from 25 to 50 per cent per pass, while on hard alloys the reductions may be only 7½ to 25 per cent. Heavy gage strip may be wound directly on the 20-in. diameter reel mandrels, and thin strip will be wound on a 2-in. thick, 24-in. diameter sleeves. In usual operation the starting coil will be fed to the mill from the auxiliary pay-off reel; however, coil charging buggies are provided to load the starting coil on the right main reel. Usual schedules will be an odd number of passes to finish the coil on the left reel; however, coils can be removed from the right reel thus enabling schedules of an even number of passes.

The wide range of strip width and thickness, wide range of steel analysis and physical characteristics and varied methods of mill operation make necessary that the control provides the maximum flexibility, and that it be easily adjustable to meet the varied operating conditions.

Mill data—Detailed data regarding the mill and reels, screwdowns, electrical drive equipment and range of operating conditions are summarized in Table II.

Mill and drives—Figure 7, taken just before the mill was put into service, shows the entry side of the mill and the entry side master control cabinet mounted on the mill housing. The strip thickness gage graphic meter, gage setup cabinet and the automatic gage control cabinet are mounted at the left of the main master control cabinet. Similar equipment is provided on the delivery side mill master control cabinet.

Figure 8 is a general view of the motor room showing the 3000-hp mill drive motor, two 1250-hp main reel motors, part of the 4400-kw power supply motor-generator set, 440-volt control center and the mill and reel drives line control panelboard. The double-door cabinet at the end of the control board at the left is the automatic gage control equipment, and the variable-voltage screw-down controller is directly behind the gage control cabinet.

The 3000-hp, 125/360-rpm mill motor with motor shunt field control, direct coupled to the pinion stand and mill work rolls, corresponds to 590/1700 fpm nominal mill speed range with 18-in. diameter rolls. The wide speed range affords full rated mill motor power down to 590 fpm for efficient rolling of stainless and other hard alloy strip. Also, it is planned to use smaller rolls, down to 16¼-in. minimum, to reduce the total roll force and afford full power at even lower speed, when rolling the hardest alloys. This 3000-hp mill motor is a duplicate of one of the hot strip mill motors in the plant.

Figure 9 shows the front panels of the substation duplex control board, with the gage control cabinet at the extreme right. This view also shows the 60-cycle magnetic amplifier regulator panels for the mill, left and right main reels and auxiliary entry pay-off reel. The control includes large switchboard type indicating meters and graphic recording meters in all main power circuits, and miniature indicating meters and adjusting rheostats in all field and regulator circuits. Figure 10 is a view of the rear panels of the substation duplex control board. These rear panels include the sequence and master control relays for the mill and reel drives. On the panels in the foreground are the motor-operated reel tension adjusting rheostats, controlled from switches and with position indicators on the mill master control cabinets, and the motor-operated reel cemf regulator rheostats controlled by the magnetic regulators on the front panels. At the extreme left of this

TABLE II
The 56-In. Reversing Cold Reduction Mill

Mill data	
Work rolls	18-in. diameter by 56-in. face (19-in. maximum to 16¼-in. minimum diameter)
Backup rolls	51-in. diameter by 56-in. face
Mill motor	3000-hp, single-armature; 125/360-rpm, 600-volts
Drive	Direct to pinions and work rolls
Nominal mill speed, fpm	590/1700
Material to be rolled	
Grades	Low-carbon mild steel, stainless and other hard alloys and silicon electrical steel
Width, in.	24 to 50
Thickness starting, in.	0.075 to 0.250
Thickness finishing, in.	0.005 to 0.075
Reduction per pass, per cent:	
Low-carbon mild steel	25 minimum to 50 maximum
Stainless and hard alloy	7½ minimum to 25 maximum
Temper passing	5 maximum
Screw-down data	
Mill screws	18-in. diameter, ¼-in. pitch
Screw-down motors	Two 75-hp, 515-rpm, 230-volt, frame 612, shunt-wound with variable-voltage control from two 75-kw generators to 500 volts
Total gear ratio	986.5 to 1
Screw speed	0.000246-in. per motor revolution 0.127 in. per min at 230 volts 0.276 in. per min at 500 volts
Entry and delivery main reels data	
Diameter of:	
Reel mandrel, in.	20
Coil sleeve, in.	24
Largest coil, in.	62
Maximum strip delivery speed, fpm	1785
Reel gear ratio	2.24 to 1
Reel motor	1250-hp, 250/775-rpm, 600-volt
Rated full load winding reel tension capacity, lb	22,200
Rated full load unwinding reel back tension capacity, lb	27,500
Range of tension adjustment, per cent	20 to 120
Auxiliary entry pay-off reel data	
Maximum nominal strip entry speed, fpm	1750
Pay-off reel gear ratio	4.1 to 1
Pay-off reel drag generators	Two 75-kw, 450/1500-rpm, 250-volt
Rated full load pay-off reel back tension capacity, lb	4300
Range of tension adjustment, lb	1725 to 5150
General data	
Distance from mill center line to:	
Auxiliary entry pay-off reel	26 ft-6 in.
Right main reel	12 ft-9 in
Right radiation thickness gage	6 ft-5 in.
Left radiation thickness gage	5 ft-11¾ in.
Left main reel	11 ft-1½ in.
Power supply motor-generator set	
Mill generator—2400-kw, 600-volt, 514-rpm, separately excited from forcing exciter and 60-cycle magnetic amplifier speed regulator.	
Left reel generator—1000-kw, 600-volt, 514-rpm, separately excited from forcing exciter and 60-cycle magnetic amplifier current regulator.	
Right reel generator—Same as for left reel. Also used to absorb regenerated output from two 75-kw auxiliary pay-off reel drag generators during first pass.	
Synchronous driving motor—5000-hp, 0.9-power factor, 200-per cent pullout torque, 6600-volt, 3-phase, 60-cycle, 14-pole, 514-rpm, with neutral reactor starting and bearing oil lift pumps.	

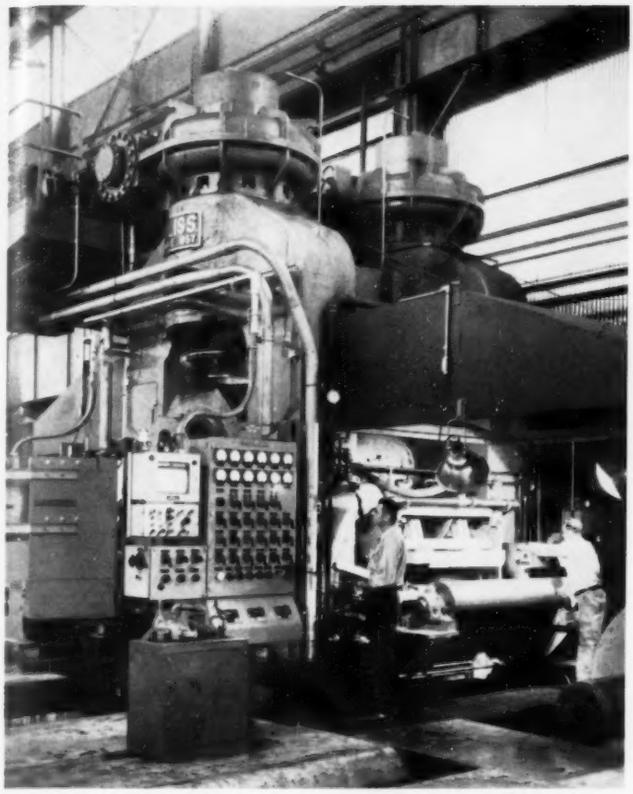


Figure 7 — The 56-in. mill is powered by a 3000-hp drive motor.

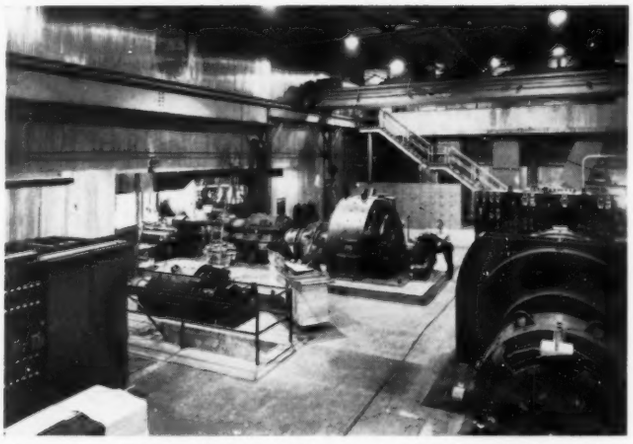


Figure 8 — The mill work rolls are driven through a pinion stand directly coupled to the mill motor.

Figure 9 — The gage control cabinet is located on the right of the substation duplex control board.

Figure 10 — The motor-operated roll tension adjusting rheostats and the motor-operated cemf reel regulator rheostats are mounted on the panel board.

board is the two-panel variable-voltage screw-down controller.

Main drive connection arrangement—Figure 11 shows the pass line elevation arrangement and simplified schematic connections for the 56-in. reversing mill and reel main drives. The main motor and generator armature circuits show the single-armature 3000-hp mill motor, the 2400-kw mill supply generator and the 1250-hp motor and 1000-kw supply generator for each main reel; however, the regulating system connections are almost identical with those shown on Figure 2 for the 42-in. mill drive.

The double-cone type auxiliary pay-off reel drives two 75-kw, 450/1500-rpm, 250-volt drag generators. These two drag generators are connected in series so they may be controlled as one machine without requiring any load balance, and their regenerated output is absorbed by the right reel 1000-kw generator since the main reel is idle when strip is being unwound from the auxiliary pay-off reel. Provision is made to enable jogging the pay-off reel from the 250-volt shop supply while the right main reel is operating from the 1000-kw supply generator, to enable loading and threading a new coil on the pay-off reel.

Gage control system—Simplified schematic block diagram for the 56-in. mill automatic gage control system is shown in Figure 12. The system incorporates the same essential fundamental features as previously described for the 42-in. mill gage control, but makes use of newly-developed techniques and equipment components, and provides much more sophisticated screw-down gage control made possible by the position-regulated variable-voltage screw-down drive.

There are two radiation type strip thickness gages, with transfer selector relays WL and WR, so the gage deviation signal input to the gage control is derived from the delivered strip for either direction of operation. Extra mill guides at the entry side of the mill forbade a symmetrical arrangement so the right gage is located 6 ft-5 in. from the mill centerline and the left gage is only 5 ft-11¾ in. from the mill centerline.

Selector switches on the master control cabinets enable setup selection to control the delivered strip thickness by: (1) controlling only the strip back ten-

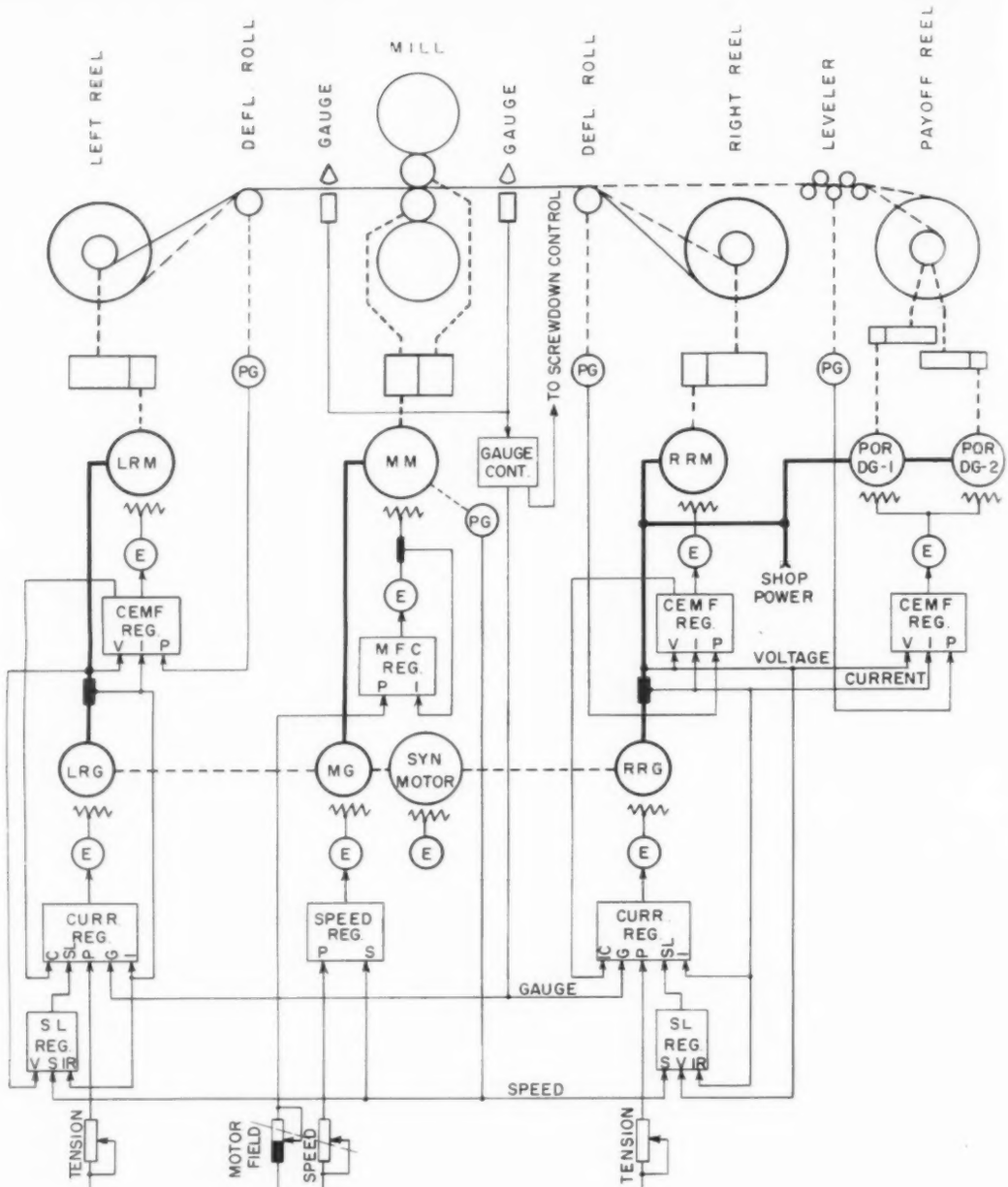


Figure 11 — The regulating system for the 56-in. mill is almost identical to the one used on the 42-in. mill.

sion; (2) controlling only the screw position; or (3) controlling both the back tension and the screw position. However, it is expected that best performance will be achieved by the combination tension and screw-down mode of automatic gage control operation.

The mill screws are 18-in. diameter and ¼-in. pitch screws, driven through a 986.5 to 1 total gear ratio by two 75-hp, 515-rpm, 230-volt frame 612 shunt-wound motors supplied from two 75-kw, 250-volt generators, and operated at up to 500 volts maximum. With this screw-down drive each 0.001-in. screw movement corresponds to 3.95 motor revolutions, and the screw speed is 0.127 in. per min at 230 volts and 0.276 in. per min at 500 volts. A magnetic amplifier regulated variable-voltage control is designed to obtain fast system response, and delay times are reduced to a minimum by arranging the control so that in the off position the clutch between motors is energized and engaged, the motor brakes are energized and released, the line contactors are closed, and the screw-down drive starts immediately. The screw-down motors are enclosed and force ventilated to provide capacity for frequent operation and for forcing for maximum response.

Tension gage control—The operation of the tension part of the automatic gage control system is essentially the same as described for the 42-in. mill, except that the sampling system is made up of transistorized modules energized from a contactless pulse generator driven from the mill motor, and the static integrator is a static transistorized computing amplifier.

The gage control is permitted to function only when the mill is running above thread speed as determined by a speed signal from the mill pilot generator. The amplified strip thickness deviation signal from the exit side gage is fed through the static integrator to the tension gage control regulator. The integrator is effective continuously at low gain and responds to all thickness errors with no dead band, thus providing excellent steady state accuracy without instability. However, if the error increases rapidly and exceeds a selected dead

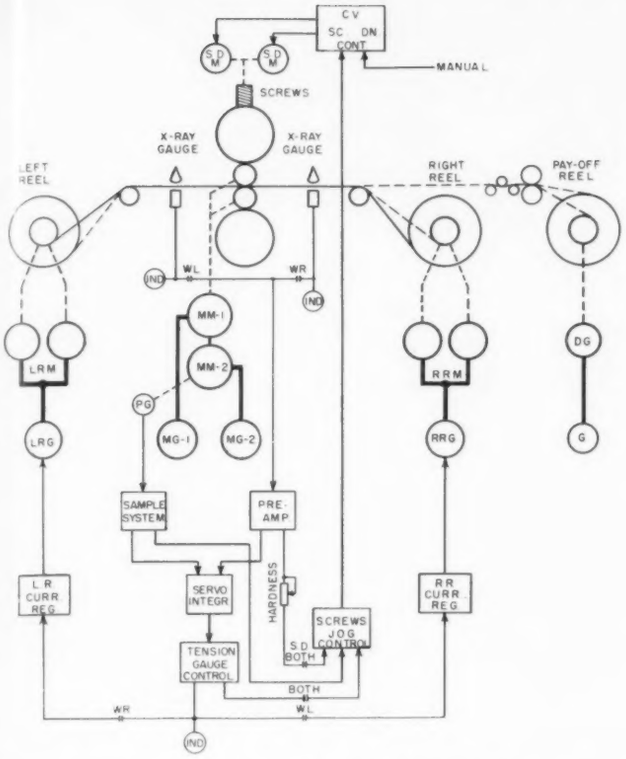


Figure 12 — A position-regulated, variable-voltage screw-down drive is used on the 56-in. mill.

band, the integrator gain is increased for a short on time to correct the gage quickly by a rapid change of back tension. The integrator high-gain rate is made proportional to the thickness error, but may be modified by a sensitivity adjustment. The static sampling system permits the integrator to operate at the high gain for the measured on time, so that the correction obtained by the fast tension change will approximately compensate for the initiating thickness error. The sampling system then does not permit another fast tension change until after an off time for the gage to see the result of the preceding fast corrective tension change, however, the integrator remains effective at its normal low gain during the off time.

Screw-down gage control—When operating in the combination tension and screw-down mode of gage control the screws are permitted to move only when the tension correction approaches a selected limit, and when operating in the screw-down only mode the screws make a corrective movement whenever the thickness error exceeds the selected dead band. However, the screw-down gage control operates so that with either mode the corrective screw movement will be proportional to the initating thickness error (as modified by a hardness switch selection), thus effecting the required correction in the minimum time and with the fewest screw-down operations. The position-regulated variable-voltage screw-down drive enables this accurate screw positioning operation.

The amplified thickness error signal is fed to the screw-down gage control, and a corrective screw movement is initiated when permitted by the tension correction limit and when the error exceeds the selected dead band. The screw-down gage control includes an "error sample hold" and the screwdown operates until its movement as indicated by the position synchro matches the "error sample" at the time the corrective movement was initiated. When the movement is completed a gating circuit releases the "sample hold" to reset the control ready for the next corrective movement. The screw-down gage control can make a corrective movement at any time, except that after each corrective movement the sample system prevents another screw-down operation until after an off time sufficient for the strip to travel from the roll bite to the thickness gage, so the gage can see the result of the preceding corrective screw movement. At 1500 fpm normal rolling speed this transport time delay is only $\frac{1}{4}$ sec or so, and screw movements are almost unrestricted; however, at low rolling speed the transport time from the roll bite to the gage may be as long as $1\frac{1}{2}$ sec.

Figure 13 is an installation view of the variable-voltage duplex screw-down controller, including the setup and manual control relays and the power stage magnetic regulators controlling the two 75-kw generators. Normally, the two motors operate together and are connected to the generators in a sandwich-series circuit. Line contactors enable operating either motor alone from its respective generator to level the mill. It may be noted that the screw-down gage control operates with a dead band, and in this dead band range there is no input signal to the screw-down control. The generators are regulated to zero voltage, and there is no circulating current in the armature circuits. Thus the screw-down motors are energized and loaded only while a movement is actually being made.

A view of the gage control regulator cabinet is shown in Figure 14. All of the transistorized circuits for the sample system, static integrator and tension and screw-down tension regulators are in the form of standardized

Figure 13 — Magnetic amplifiers are used to control the 75-kw generators for the screwdowns.

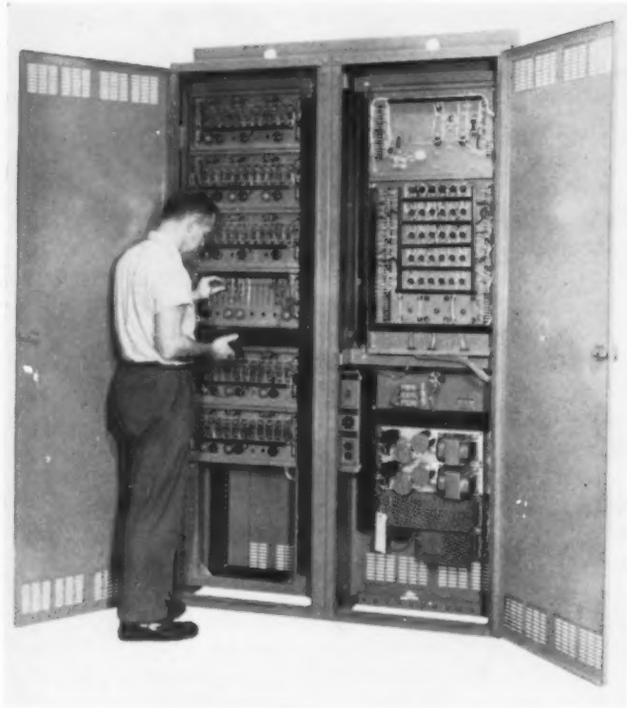


Figure 14 — Use of standardized modules permits ease of replacement.

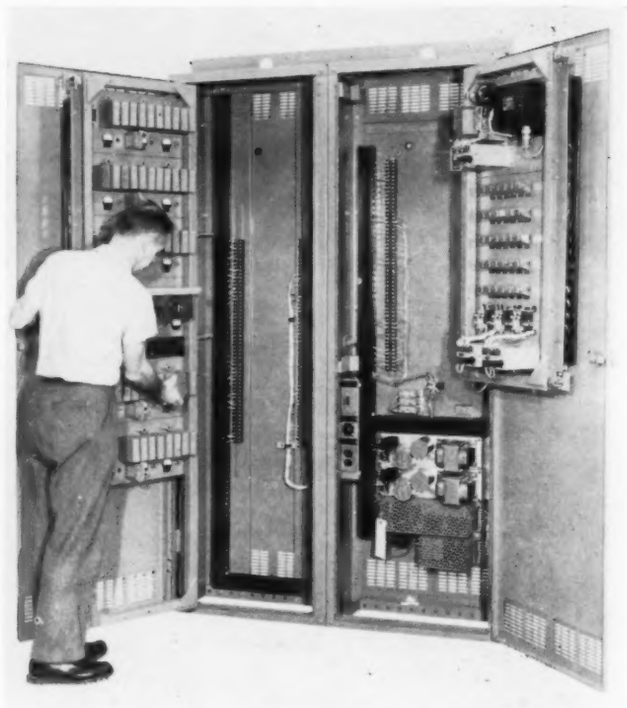


Figure 15 — The cabinet bays swing out to permit access to the rear of the control panels.

encapsulated modules to enable easy checking for maintenance and trouble shooting, and to permit replacement of the entire functional circuit module. The transistorized circuit modules and other equipment components are assembled on hinged bays in the shallow enclosing cabinet so that the front and back of the bays are easily accessible through the front cabinet doors. Figure 15 shows the gage control cabinet with the bays swung out to afford access to the back of the gage control panels and to the terminal blocks and external wiring.

OTHER GAGE CONTROL INSTALLATIONS

Designs are progressing on several additional single-stand mill gage control systems. One of these is for a small brass and copper rolling mill and will be a combination tension and screw-down system, with all static transistorized logic and computer circuitry, and providing selective screw-down jogging with a constant-voltage magnetic controller.

Another mill will be a 6 and 30 x 30-in. single-stand 4-high reversing mill, with driven backup rolls, operating up to 1500 fpm maximum and intended primarily for the cold reduction of stainless and other hard alloy steels. The backup rolls will be individually driven by two 500-hp mill motors constituting a 1000-hp twin-motor, and each main reel will have two 300-hp motors, one with a disengaging clutch so that one motor may be used for light tension and both motors together for heavy tension. The screwdown will be variable-voltage. The automatic gage control system will be essentially the same as described in this paper for the 56-in. mill, and will be of the combination tension and screw-down type, with a low-gain continuous integrating and high-gain sampling tension gage regulator controlling the unwinding reel, and a sampling screw-down gage regulator controlling the position-regulated variable-voltage screw-down drive.

SUMMARY

The descriptions of these modern single-stand reversing cold reduction mills illustrate the control and regulating systems which have been developed to afford accurate and effective strip thickness control. The combination of a low-gain continuous and high-gain sampling tension gage control system to obtain fine control over a limited range, and a sampling screw-down gage control system operating over a larger range, provides an over-all system featuring fast response, stability, sampling correction proportional to initiating error and high steady state and transient accuracy. Development of transistorized logic and computer circuitry and magnetic regulators enables a completely static control and regulating system. Entirely practicable systems are possible using constant-voltage, magnetic screw-down control; however, a position-regulated, variable-voltage screw-down drive enables more precise operation.

Does the author feel that the added complication of a screw-down position regulator is justified from the standpoint of gage control performance? Perhaps it would be more to the point to ask whether the added expense of adjustable voltage screw-down drive is justified, as far as the gage control is concerned. It seems that the screw-down control is basically a coarse regulator, which serves to keep tension within range. The author has demonstrated that the constant-potential control will do this, but has not shown how the adjustable voltage control will improve it.

Discussion

PRESENTED BY

R. M. SILLS, Metal Rolling and Processing Engineering, Industrial Engineering Operation, General Electric Co., Schenectady, N. Y.

A. J. WINCHESTER, Chief Electrical Engineer, Rolling Mill Div., E. W. Bliss Co., Salem, Ohio

E. V. EISENBERGER, Electrical Engineer, Alan Wood Steel Co., Conshohocken, Pa.

C. J. BEVAN, Electrical Engineer, Bethlehem Steel Co., Sparrows Point, Md.

ROBERT D. REILLY, Plant Manager, Signode Steel Strapping Co., Baltimore, Md.

E. H. CHRISTIAN, Electrical Engineer, Control Dept., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

ALONZO F. KENYON, Advisory Engineer, Industrial Engineering Dept., Westinghouse Electric Corp., East Pittsburgh, Pa.

R. M. Sills: The author's conclusion that a combination of screwdowns and back tension produces the best results can be readily agreed with. This fact concurs with the conclusions reached by Phillips and Maxwell in an article published several years ago, "Automatic Gage Control for Cold Reduction Mills" 1960 ASME Proceedings p. 503. It also confirms field and computer experience.

Using the data presented by the author, the tension transfer function obtained is not over 0.25 to 0.5 mils per 100 lb per in. of width. This is less than one half of the values measured by several investigators. Is this difference because the strip was silicon steel? Are any figures available for the 56-in. mill or any other mill rolling carbon steel?

The author makes the statement that it is undesirable to change the back tension by more than 250 amp, which is about 13 per cent of maximum tension. Is this limitation a function of strip thickness, or tension being held, or is it an absolute limit? In the author's opinion, what are the reasons for a fairly narrow tension limit?

A. J. Winchester: Automatic gage control for single-stand mills has not received the attention and the emphasis given to some of the more glamorous mills; consequently, the progress made is not as great. There are a number of single-stand mills with automatic gage control, but most of this control is rather crude. This paper shows evidence of some substantial steps in the direction toward more sophisticated gage control; for example, the continuous slow correction to maintain accuracy is excellent.

Customers frequently ask for recommendations concerning the type of drive to use for screwdowns when adjustable-voltage control is used. An adjustable-voltage drive gives the best performance and is the most expensive. It is possible to use a d-c drive with a constant-voltage controller. Some mills have a-c screwdown drives which are operating satisfactorily with automatic gage control. However, optimum performance and minimum maintenance is obtained with an adjustable-voltage drive.

Control of screw movement by means of a feed-back system is an improvement over allowing the screws to move for a definite time when a correction is required.

Not much is said about maintaining gage by controlling front tension. The author discusses maintenance of gage by control of back tension. Manipulation of back tension rather than front tension is recommended because changes in back tension will not affect the way the coil is wrapped on the winding reel. Would the author like to comment on why back tension is used and why front tension is not used for automatic gage control?

There was some reference to brakes on screwdowns. On a cold mill, a brake does not serve a useful function and could in many cases be eliminated. For example, for a small correction it is provable that the brake does not offer much help in stopping the screw, because with adjustable-voltage control and even with constant-voltage control, the motor will probably stop before the brake has time to set. Would the author like to comment as to his recommendations on brakes for cold mill screwdowns?

E. V. Eisenberger: As the author points out, automatic tension control, although fast operating and capable of continuous use, is limited in range. Automatic screw-down control has a large range, but it is inherently slow and requires frequent jogs. A combination of both methods, coupled with an increase in screw-down control response time and transistorized, static circuits, should be the solution.

The author pointed out that the 42-in. mill is equipped with two X-ray type gages and the 56-in. mill has two radiation type gages. Why are these gages not the same type? Are the gages provided with traversing control so they may be removed from the pass line during threading operations?

C. J. Bevan: The use of gage control on a single-stand reversing mill is one of the many technical applications of fast response electrical systems that replace the attempt to do such things manually. Many of the components the author described as a functional part of this type of installation are in use at Sparrows Point, and their use is radically changing the scope of work done by the maintenance departments.

The trend of all automatic systems such as data processing, card programming, automatic gage control and control computer systems is increasing the demand for highly-skilled maintenance technicians. Experience with transistorized control has not indicated that this equipment is fault free, and trouble shooting on static control means a strenuous steel plant educational program.

It also requires an educational program to have the operating departments use this type of control when it is available.

Sparrows Point has had automatic gage control since 1957 on a 5-stand tandom mill. As the author indicated, the use of tension control and screw-down control produces the most desirable on-gage strip. The gage mounted on the delivery side of stand 1 acts as the coarse screw-down adjustment, with the gage after stand 5 controlling the vernier tension adjustments.

Since its installation two features that improve the

over-all system have been added. The first of these is to force the field of the winding reel to more closely speed match stand 5, thus producing a better coil, and the second is to increase the tensions between stands 1 and 2 during acceleration by strengthening the field of stand 1 motor from the rate-of-change regulator.

With this arrangement, the strip gage has been maintained within 0.2 mil at operating speeds averaging 4500 fpm. This mill is a 6000-fpm mill, but it is not operated that fast.

Would the author like to give his thoughts on the use of load cells in lieu of X-ray gages, and what is being done in the way of hydraulic control on the screw-down motion?

Is it possible to have the same accuracy on a single-stand mill as it is on a 5-stand mill where tension control and screw-down control are completely separate?

Robert D. Reilly: What are the possible personnel hazards, with X-ray or radiation gages?

E. H. Christian: Has it been necessary to clamp the integrating control periodically during running of a coil to minimize drift or are some of the more elaborate analogue computing techniques employed for drift stabilization?

In evaluating the gage control results, would the author care to comment on the relative finish characteristics (shape, flatness, appearance) with back tension control, screw control and both simultaneously?

Is the gage control operative on the welds in the charts shown?

The use of brakes on a variable-voltage screw controlled mill is not recommended particularly if position feedback is used.

For high speed of response systems the electrohydraulic vernier control looks very promising.

Alonzo F. Kenyon: There has been no attempt to correlate the gage with actual tension change, but only to report observations made of the mill operation. As has been indicated, the 42-in. mill operates almost entirely on silicon electrical steel. Such steel work hardens quite rapidly and the power requirements are much higher than for low-carbon steel. It is felt that this is the reason for the smaller gage correction for a given tension change.

Although the mill was intended for both the roughing down and the finish rolling operations; actually during the few months the mill has been running, it has operated almost entirely on the light gage silicon strip finishing, and there has been no opportunity to see what the operation would be on heavy gage silicon nor on carbon steel. Although the full load current to the two 700-hp reel motors is about 1850 amp, the usual running tension loads when making the light gage finishing passes are on the order of 1000 amp, therefore, the permitted 200 to 250 amp change on the tension gage control represents a plus or minus range of 20 to 25 per cent from the usual operating tension.

A fundamental feature of practically all of our gage control systems, has been to make a correction, both in the sampling tension control and in the screw-down control, which is, as nearly as practicable, proportional to the gage deviation at the time the correction is initiated. The position-regulated variable-voltage screw-down does enable more precise control for small screw-down positioning movements than is possible with a timed jogging operation from a constant-voltage magnetic controller.

On the reversing mill, the position-regulated control also may be utilized to enable the operator to select the screw-down setting for each succeeding pass while the preceding pass is being run, and the setting for the next pass then is made automatically when the mill stops.

At least one system has been built with a selector to enable the operator to select for both front and back tension control. However, operating experience and analytical study indicate that variation of back tension is more effective in controlling gage. Also most rollers like to maintain uniform winding tension in order to get a smooth coil, as variations in winding tension may affect the tracking of the strip onto the coil.

With the necessary small screw pitch and large gear ratio, the screwdown is self-locking so brakes are not needed to hold the drive from backing off, and admittedly are not fast enough to help much in stopping. Certainly on a variable-voltage drive, the brakes could be eliminated. It may be noted that brakes have been omitted on several automatic positioning drives such as blooming mill manipulators, as response time usually can be materially reduced.

Present gage control systems operate from low-power-level control signals, which are available from different types of X-ray and radiation gages, and usually the gage control system can be made to operate successfully with the type of gage which a particular customer may prefer. However, since the gage control has high amplification and extremely fast response, it is necessary that the noise level of the gage output signal be kept low.

On both of the mills described, the gages are of the traversing type, so they can be withdrawn from the pass line. However, a number of installations have been made on other mills, where the strip thickness gages are fixed in position.

Thus far, it is felt that this new type equipment has earned a good service record, and that in general it can be serviced and maintained by properly trained steel plant personnel.

Our first installation of hydraulic-operated screw control on a hot strip finishing mill is being made, and undoubtedly this method will find use in gage control systems for both hot and cold strip mills.

It is felt that there is no reason why the same degree of gage accuracy should not be achieved on a single-stand reversing mill as on a tandem cold reduction mill. ▲

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ASSOCIATION OF IRON AND STEEL ENGINEERS, 1010 EMPIRE BLDG., PITTSBURGH 22, PA.

A Training Program for Key Electrical Maintenance Employees

DR. JOSEPH S. KOPAS
Training Counselor
Republic Steel Corp.
and Director
Human Engineering Institute
Cleveland, Ohio

The increasing complexity of steel mill equipment necessitates re-educating maintenance forces so they have the required capability to perform their duties.

IN recent years, rapid and accelerating technological progress has ushered in a critical and difficult personnel problem for industry. This problem is the deterioration in the job performance of older employees.

Technology has a way of racing ahead of the previously acquired skills of the men who press the buttons, pull the levers and maintain the machinery. Now technology threatens to widen the gap even more between the worker and his job, to the point where the senior employees could lose out altogether.

Some examples are provided in the steel industry where production units have been modernized through the installation of hydraulic and electronic equipment. Because hydraulic systems involved a great deal of piping, the job of maintaining these systems fell to pipefitters. Similarly, electric motor inspectors inherited the responsibility for looking after electronic equipment because it bore a general relationship to their field and involved electricity.

In both categories these employees were senior employees with many years of experience. They were first-class workmen performing key jobs, but their knowledge of the more advanced technical equipment was inadequate, and their job performance fell off sharply.

This erosion of the job performance of senior employees on key jobs resulted from a shift in emphasis from physical or motor skills to mental or reasoning abilities. The comments of a steelworker who had recently been transferred from an outmoded bar mill to a brand new semi-automated mill illustrates this point: "The mill makes it easier physically. You do not have the heavy sledging anymore, but automation makes you think."

In the past the job itself had provided the practical knowledge, experience and the necessary practice for motor skills. This was largely what the job required. The modern job, however, calls for much more than motor skills. It requires the exercise of judgment and thus makes the acquisition of technical background and related knowledge essential for effective job performance.

These new, more stringent job requirements place the greatest burden upon senior employees. A survey revealed that these older men had the least amount of schooling, eight years on the average, and had been away from school on the average for about 30 years. Among all employees, these key men were least able, from an educational standpoint, to help themselves meet the severe demands of technological progress. Yet they had on the average over 25 years of job experience and a strong, unbending faith in the value of this experience. Most of them had become first-rate workmen largely through experience and experience alone.

It can be readily seen that this presented a unique personnel situation. Because of age, educational limitations and attitude toward theory, these men were seemingly poor training risks. In addition, they exhibited very little motivation of the type typical of young men eager to make good. Thus, the prevailing attitude among management was, and in many instances still is: "Why bother with these older employees? They will retire soon anyway. They are not interested in

training. Besides, you cannot teach an old dog new tricks. Forget about them and concentrate on the younger employees who are ambitious and have a fairly good background of technical knowledge to start with." This attitude of futility was widespread and simply added to the obstacles that delayed effective solutions to the problem.

Nevertheless, this unique personnel situation kept pressing for attention because the need for doing something about it kept growing in importance. Furthermore, this need was mutual, involving both the company and the employees.

From the company's standpoint the problem was acute because these senior employees were on key jobs and their job performance was therefore critical to the company's operations. As their job performance declined, the effects spread throughout an entire department. Yet these men, on the average, had approximately 17 additional years on these key jobs if they continued until normal retirement age of 65. The longevity of the damage they could do demanded that something be done.

From the point of view of the senior employees themselves, their job success was being jeopardized in a way that seniority was unable to prevent. Their esteem in the eyes of fellow workers was being lost and they themselves were aware that they were losing their grip on their jobs. Their pride in achievement and confidence in their ability to handle their work were threatened. Their years of experience seemed of little avail, and even though they had security provided by the union through seniority provisions, they began to fear technological displacement.

After long and careful analysis of this problem, management decided that despite the obstacles that existed, the only solution, if there was a solution, was training. A check with other companies revealed that although many were conducting sound, practical training programs of one type or another, none were designed for this particular situation. Furthermore, a study of off-the-job training and educational activity of persons working at Republic's Cleveland steel plant revealed that a mere fraction of these employees was enrolling in such programs and that scarcely more than one third were completing their courses. Even worse, nearly three fourths were taking courses totally unrelated to their jobs.

Thus, in 1955, Republic's management decided to proceed with the development of a training program that was conceived and recommended for hourly employees on key production and maintenance jobs. They further designated that the program be carried out initially on a pilot, or experimental basis.

The Human Engineering Institute was selected to develop and carry out this program on a voluntary enrollment basis among the employees affected. It was assumed that if an effective program were developed to meet the needs of these senior employees, their interest would provide the necessary motivation to get them to attend on their own time. Attendance would be a major criterion of success, for the employees would enroll and complete the courses only if the training met their needs. The development of this special training program extended over a 4-year period.

TABLE I
Outline of the Electrical Maintenance Training Program

Electrical I	
Unit I	—Fundamentals of electricity
Unit II	—Magnetism
Unit III	—Generation of electricity
Unit IV	—Application of the fundamentals of electricity to d–c machinery
Unit V	—D-c motors
Unit VI	—D-c motors
Unit VII	—Compound-wound motor
Unit VIII	—Development of d-c motor control and blueprint reading
Unit IX	—Review of basic mathematics
Electrical II	
Unit I	—A-c circuits
Unit II	—Induction motors, motor connections
Unit III	—Starting motors
Unit IV	—The wound-rotor induction motor
Unit V	—Wound-rotor motor starters
Unit VI	—Synchronous motors
Unit VII	—Synchronous motor controls
Unit VIII	—Induction motors
Electrical III	
Unit I	—Principles of variable-voltage controls for d-c motors
Unit II	—Principle of the rotating regulator A
Unit III	—Principles and maintenance of rotating regulator B
Unit IV	—Magnetic amplifier
Unit V	—Transformers
Unit VI	—Fundamentals of vacuum tubes
Unit VII	—Triodes and simple amplifiers
Unit VIII	—Rectifier circuits
Unit IX	—Filter circuits
Electrical IV	
Unit I	—Voltage regulator circuits
Unit II	—Electronic power supplies
Unit III	—Thyratrons
Unit IV	—Ignitrons
Unit V	—Phototubes
Unit VI	—Synchronous motors and generators
Unit VII	—Synchronous differential motors and generators
Unit VIII	—Synchronous control transformers
Unit IX	—Transistors

THE PILOT TRAINING PROGRAM

Basic requirements—Management asked that these basic requirements be met in setting up the pilot program:

1. That the enrollment be voluntary, at no cost to the employees, and that employees attend classes on their own time.
2. That the programs be designed and developed to meet the needs of employees by major operating departments.
3. That the program be started initially in only a few of the departments, where the department heads were interested and wanted to undertake it.

All of these requirements were important for the success of the program.

The first year—Six departments chose to cooperate in getting the program under way. They were: coke plant, blast furnace, open hearth, strip mill, mechanical and electrical departments.

The following constituted the announcement made.

Republic will embark on a new training program designed to help key operating and maintenance wage roll employees keep pace with the progress in developing and installing new processes, new facilities and new equipment.

These training courses at the start will be given to personnel from a number of departments of the Cleveland district as well as to men working in several manufacturing divisions in or near Cleveland. As the program evolves, it will be extended to other departments and other districts.

The program is designed to provide employees not only with a greater depth of knowledge concerning the technical aspects of their jobs but also a greater breadth of understanding regarding why they do the things required of them. It is felt that if they have an understanding of the why of their jobs, and how their functions fit into over-all productive processes, they will be better equipped to exercise good judgment in handling the varying problems that arise day by day.

The program includes three courses for each department, developed in cooperation with department superintendents. The courses are conducted at the Human Engineering Institute, a nonprofit organization created for the development of programs aimed at better and more effective use of manpower. Courses are ten weeks in length, 1½ hr per session.

Senior employees in the top of the job progression who can absorb and benefit from the training are given the first opportunity to enroll. Enrollment is based on the recommendation of department heads and is purely voluntary on the part of the employees recommended. Attendance is on the employees' own time. There is no tuition; Republic is financing the entire cost.

Courses will be offered each year in each department. Successful completion of each course makes the employee eligible for recommendation to the succeeding course.

Interest in the program will undoutedly be high. Only 200 employees will be enrolled in the course this year.

Announcement of the training struck a harmonious chord among the supervisors and union leaders. It was favorably received, in fact welcomed. The major complaint was that it should have been started at least ten years ago and that not enough employees were being given an opportunity to enroll.

This enthusiastic support on the part of the union leaders was backed by an unusually high and unexpected enrollment on their part in the first classes. Shortly after the program got under way, the supervisors expressed a desire to obtain similar training and were later given the opportunity.

Selection and training of instructors—Each superintendent was asked to recommend two instructors and an alternate. In four of the departments the superintendents and their assistants decided they would like to become the instructors. Their decision, which proved to be highly beneficial to the program, was influenced by the fact that their senior employees in key jobs would constitute the first classes and because they wanted to assume personal responsibility for the successful conduct and development of the program in its beginning stages.

The instructors were provided with three half days of training. The training consisted of the following topics:

1. Introduction to the industrial training program.
2. The role of the industrial teacher.
3. Basic purposes of each meeting.
4. Keys to creative learning.
5. Approaches to conducting sessions.
6. Techniques in the creative approach to learning.
7. Appraisal of teaching.
8. Suggestions for improvement.
9. Summary.

Selecting and enrolling the employees—Each department head conferred with his foreman to decide on the employees to be recommended as candidates. It was assumed that only about 50 per cent of those recommended would enroll. To avoid the possibility of having classes with more than 15 to 18 people, only 40 employees were placed on the recommended list from each department. If an insufficient number enrolled, names of additional candidates were to be submitted.

Two sections (A and B) were formed. Section A was the starting class, and section B was a trailer class that started a week later. Having two sections meeting a week apart made it possible for the employees enrolled to attend each session regardless of the shift they were on. Since the men worked on one of the three 8-hr shifts (day, evening and night) and rotate shifts each week, if a trailer section were not available, the men on the evening turn, 3:00 P.M. to 11:00 P.M., would miss their class session once every three weeks.

The employees who were recommended for the training were notified by a letter which was sent to their homes.

The Classroom—On the opening night these students found themselves in classrooms that were equipped with comfortable semi-upholstered chairs, arranged so that four or five could sit around a table. Scratch pads, flannel boards and other types of visual aid equipment were available. Ash trays to permit smoking added to the general informality of the classroom.

Classes started at 7:00 P.M. and lasted for 1½ hr. The school year which started in September consisted of three, 10-week quarters. (Classes were not held during the summer quarter because of vacations.) Only 205 employees were enrolled in the first year.

In nearly every instance the men knew each other and the instructor. Likewise, the instructor knew most of the men in the class. After an exchange of greetings and some kidding remarks, each class got under way in a friendly yet serious way.

Development of text material and visual aids—The superintendents of each of the six departments sat down with the members of the Institute staff responsible for the development and supervision of the program, and discussed and outlined the major topical areas to be studied in a logical sequence. Each major topic was then broken down into units and into class session outlines. This was done by a development team of three Institute staff members who worked with each instructor. The 3-man development team consisted of: (1) a person who had training in technology and experience of steelmaking; (2) an individual who knew teaching methods; and (3) a visual aids specialist. They worked regularly with the instructor preparing the text material, deciding on the best methods of teaching it and designing and preparing the visual aids that would make his instruction effective. They planned four weeks in advance and added to his text material each week.

They also coached the instructors and helped them write and illustrate their text material.

Participation of the motor inspectors—Twenty-seven motor inspectors enrolled in the electrical maintenance department training program. Over two thirds completed the first year and continued to enroll for advanced training for three more years. In the spring of 1960, 17 of the motor inspectors received a diploma for successful completion of four years of training.

This fall there will be 255 motor inspectors attending classes in the five training centers. The electrical maintenance training program is given in outline in Table I.

SUMMARY

Although the 4-year pilot program involved many instructors and hundreds of students, the fundamental concept of the program was simple.

Republic Steel Corp. had many senior employees on key jobs who had years of practical experience but lacked the technical knowledge necessary for effective performance of their present jobs. The corporation also had management personnel who had a wealth of practical experience and the technical knowledge necessary for effective instruction. In the past the two had never come together.

The pilot program provided the management personnel with the necessary help to organize and plan their instruction and to present it effectively to the senior employees under pleasant conditions and within a favorable educational environment. This, in essence, was the training key to this unique personnel situation.

In recognition of the problems involved in measuring the effectiveness of training it was assumed at the outset that the attendance would be one of the major criteria of success.

Enrollment, attendance and per cent of completions were far higher than the most optimistic hopes. Interest on the part of employees and management was high. Employee interest was reflected in regular attendance, enthusiastic participation and demands for further courses. Management interest manifested itself in the rapid spread of the program through the Cleveland district and the expansion of the program to other major steel-producing plants of Republic Steel Corp.

In view of the small classes, extensive use of visual aids and the necessity for developing the program on a going basis while training was in progress, the cost of this training proved reasonable. It averaged $100 per year per student, or a total of $400 for a student completing the 4-year course. Taking the case of the average trainee, the cost represented an annual investment of approximately $24 for each of the 17 remaining years of anticipated service. Compared to the average income of $6600 a year earned by a motor inspector, an annual investment of $24 for improved performance must be regarded as relatively insignificant.

Specific data on the improvement of operating and maintenance efficiency are difficult to obtain in this type of training situation for there are so many other factors that enter into the picture. However, the results have been readily apparent to the management of the operating and maintenance departments in terms of both performance and morale.

Significant personnel factors—The personnel aspects of this program appear to be as basic to success as the educational factors. The decision to conduct the training outside the company premises, and with voluntary enrollment on the employee's time has worked out well. The broadening of the program under the acid test conditions of continual and sustained attendance on the part of the trainees has challenged the caliber of the program and furnished a continuous yardstick as to its effectiveness. In addition, these features of the program, particularly attendance on the employee's own time, made the project economically feasible for the company. Otherwise the cost of training would have been prohibitive.

Having the program developed and conducted by a third party appears also to have been sound, especially in view of the fact that both the instructors and the students were from the same organization. This approach tended to insure that the training was conducted on a planned, organized basis utilizing sound educational principles that were made readily available to the instructors.

Organizing the instruction by departments and using departmental management personnel as instructors also contributed significantly. The class grouping was homogenous in terms of the educational focus of the class and plant operations performed. The instructors had the same practical experiences as the students; therefore, they were able to relate and integrate the theory with practices the employees understood.

The decision to develop the program "in action" and on an experimental basis rather than trying to mastermind it beforehand appears to have been helpful. It enabled the instructor and development center to meet the needs of each class situation by adjusting the type of material, amount of material covered, methods of instruction, and the reading and study material to each course and class as they progressed.

It should be noted also that the personnel policy decisions involved could not have been made in a vacuum. Their importance had to be carefully weighed in relation to the effect they would have on the educational aspects of the problem. For example, although it is difficult to prove, the program development staff agree that the decision to train the employees by departments was of tremendous importance educationally. Furthermore, it became very evident as the program progressed, that the personnel policies regarding voluntary enrollment and class attendance on the employee's own time were key factors in the effectiveness of the training program involved.

Educational factors—One of the significant factors in this program was the fact that it brought together in an effective way some well-known educational principles and techniques.

Some of these appear to be of particular significance. The organization of the classroom itself was unusual. Small classes in a small room, men grouped in comfortable chairs around tables, smoking, a relaxed and easy air of informality, all proved to be features contributing to a most suitable classroom environment.

The curriculum was designed on the principle of relating technical theory to practical experience, thereby giving a broad view of the total operations of the department. In the second and third years more and

more emphasis was placed on the theoretical and less on the practical, but continued attention was given to weaving the theory into the employee's practical experience. During these years, the curriculum expanded in both breadth and depth, introducing one logical phase of the total operation at a time and developing a thorough understanding of the technology involved. In developing the curriculum, both the development staff and the instructors made valuable contributions.

The teaching methods employed are well known. In training the instructors, it was referred to as creative teaching. Their goal was to help students learn rather than merely to cover a certain specified body of knowledge within a certain time. In this connection the text was used to supplement teaching; it was a general guide to what should be taught.

The generous use of educational and visual aids proved helpful in presenting some of the technical concepts, particularly in relating these concepts to the experience of the men.

Because of certain limitations inherent in the nature of the pilot program itself, it cannot be proven that this necessarily presented the best way the problem could have been handled. However, the extraordinary attendance record of trainees coupled with their enthusiasm and request for more advanced training provides convincing evidence that this program fulfilled specific training needs to a degree far beyond anything developed up to that time.

Discussion

PRESENTED BY

W. M. KRUMMEL, Steel Mill Application Engineer, Metal Rolling & Processing Engineering, Industrial Engineering Operation, General Electric Co., Schenectady, N. Y.

C. J. BOYLE, Assistant to Superintendent, Electrical Dept., Bethlehem Steel Co., Bethlehem, Pa.

DR. JOSEPH S. KOPAS, Training Counselor, Republic Steel Corp., and Director, Human Engineering Institute, Cleveland, Ohio

JOHN H. GREINER, Supervisory Engineer, Industrial Systems Dept., Industrial Equipment Div., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

JOHN J. TIMBERLAKE, Superintendent of Assigned Maintenance, Middletown Works, Armco Steel Corp., Middletown, Ohio

W. M. Krummel: Certainly the electrical manufacturers bear a considerable share of the responsibility in introducing and promulgating the latest in electrical techniques and equipment. Therefore, it is logical to expect that the electrical manufacturer will want to partake in the effort to maintain a high level of competence and understanding in the maintenance and operating people.

The electrical manufacturer is naturally interested in the successful operation of his equipment over a long time. To help ensure this, the manufacturer designs equipment for the steel industry that is rugged, reliable and as simple in operation and maintenance as possible. However, the necessities of industry automation has forced increasing complexity. The latest in electronic techniques are utilized in equipment in order to provide equipment that is reasonable in size and possesses the required very fast responses, high accuracies and complex operation features. Circuits, techniques and applications are so new that even recent engineering graduates may find themselves somewhat out of date.

The steel industry must make use of this equipment if it is to advance. How then is it to ensure equipment maintenance for successful operation?

The first step is shown by the author to be one of providing the opportunity for electrical maintenance men to be grounded in the fundamentals of their work.

The next step is a cooperative venture between the steel plant and the electrical manufacturer on the occasion of the installation of new electrical equipment of a type that is largely unknown to the personnel of the steel plant.

As an example of this second step, take the new 56-in. hot strip mill of the Republic Steel Corp. The motor drive power supplies are made up of banks of ignitron mercury arc rectifiers. Firing is controlled by circuits using a new static device development, the silicon controlled rectifier. Completely new high-gain, fast-response speed regulator controls and automatic gage controls, both based on module type transistorized circuitry are being furnished. Included also are complex instruments such as X-ray and width gages.

It was recognized early in the project that a training program was needed for electrical maintenance personnel on the new mill. The program organized was made up of four phases.

Phase 1 was an indoctrination portion designed for higher level supervisory and management personnel to acquaint them with the scope and features of the project and also to enlist their support in providing proper incentive to the selected maintenance personnel.

Phase 2 was a 40-hr introductory session with the selected group of maintenance men devoted to reviewing fundamentals and covering in detail a majority of the features of the equipment. The instruction book for the equipment was used as a text.

Phase 3 carried on the work started in phase 2, in greater detail and thoroughness. The trainees supplemented their classroom instructions with visits to the production aisles and test areas to witness the assembly and testing of the equipment that they would be responsible for maintaining.

Phase 4 was a more loosely organized period and consisted of periodic short classes during actual installation and final adjustment of the equipment. At these classes adjustment maintenance techniques were reviewed.

The instructors for this program were provided by the equipment supplier and represented system design, product design and district service for the various phases of the project.

The Human Engineering Institute assigned one of their personnel to attend the class sessions who was responsible for aiding in the setting up of phase 5 of the program. This last phase consisted of a continuing program to aid in keeping the electrical maintenance personnel up-to-date with current practices in their

work and to take into account normal personnel turnover.

This so-called last phase of the program can be considered as actually the third step in the over-all training of steel plant maintenance personnel: a self-sustaining program designed to maintain the level of competence achieved by the first two steps.

C. J. Boyle: Automation and electronics became a problem at the Bethlehem plant ahead of the rest of the industry because of the large manufacturing division, which for some years has had the problem of maintaining complicated electrical controls on major machine tools, presses, furnaces, etc.

An apprentice program for electrical and general maintenance from which trained maintenance people were obtained was discontinued in the 1947–1948 period, when all maintenance jobs were classified as multiple rated jobs.

Experiments with a helper training program were discontinued because it was found that as the helpers completed their training, because of the problem of selling increased seniority, because of increased ability, there was no place for them to go.

Plans have been formulated for an up-grade training program which should help solve the problem at Bethlehem and provide qualified people to assure proper maintenance of any advanced technical equipment that might find its way into the plant.

The idea that the author's program is carried out away from the plant on the trainee's own time, is particularly interesting also, the idea of having the program developed by a third party appears sound. The idea of plant supervisory people being used as the instructors in the course is quite good.

How did you conclude that the program should stretch out over four years? Is four years too long? After all, it covered one fourth of the average working time remaining to the employees prior to retirement.

What was the correlation of drop-outs with respect to years of employment remaining until retirement?

Who determined and how was the determination made as to the senior employees who could absorb and benefit from the training?

Did the program have to receive union approval, and did the feeling of the union, which you say thought highly of the program, influence the enrollment?

It was indicated that the major number of drop-outs were in the first year. Would the author tell us why and if any effort was made to re-interest those people?

What minimum attendance was required? Were men dropped because of absenteeism?

Was a certain level of proficiency necessary to continue with the course or was attendance the only requirement?

Were company men who conducted the course compensated for instruction time?

What recognition did graduates receive other than a diploma? Did completion of the course in any way influence promotions after graduation?

Dr. Joseph S. Kopas: At the start of the training program it was expected to last only one year, but at the end of each year of training the men asked for additional training. The program, as a result of their own interest and request, evolved into a 4-year project. At the end of four years, they were asked, "is four years too long?" Their answer was, "no." Periodic requests for advanced classes to bring these graduates up-to-date on the new things that are happening, especially in the electronic field are made.

The number of drop-outs was so small that it is difficult to make a reliable study. It was found that training has a universal appeal for the older worker, particularly if the training is practical and supplies the employee with a better understanding of the technical phases of his job. Some of the drop-outs are expected to re-enroll and complete the 4-year training program when the reasons for the drop-outs no longer exist.

Determination of employees was made by the head of the department. If in his estimation a senior employee would have difficulty attending for physical resaons or would not benefit from the training because of lack of interest or other difficulties, he would not recommend that he be invited to enroll. However, if a senior employee was not recommended, and desired to participate in the training, the department head added him to his list of recommendations.

The union was informed of the intention of the company to start the training program, and they were asked for their cooperation, but no approval was sought or thought needed. Many of the union leaders are senior employees and for that reason were recommended by the department heads as enrollers for the training program. The enrollment was surprisingly high. It was expected that 50 per cent of the employees recommended would enrol[1] Classes were doubled from the start because over 90 per cent enrolled. The fact that union leaders, as well as other employees, enrolled in large numbers, indicated that a need for such training was the major influencing factor in the enrollment.

One of the major reasons for drop-outs was the quality of instruction. It takes time to affect good instruction, to develop the necessary visual aids and to organize interesting text material. Another reason was the lack of follow through. A third reason was the fact that the program was new and that not too many understood the nature and the purpose of it. It was noticed that some of the drop-outs are now starting over again in the continuing groups at the point where they dropped out.

Attendance was to be the major criterion for success of the training program. It was mentioned that Charles M. White, when he approved the program, asked that the attendance of the training program be strictly voluntary and on the employee's own time. Under such conditions only the employees who are really interested in the training would enroll, and would continue attending only if the training took care of the need they had for such training. If the training was not interesting, meaningful and purposeful, they would cease to attend. For this reason attendance was considered the major criterion of the effectiveness of the training program.

A minimum of 70 per cent attendance was required for completion of the training and for the opportunity of continuing the training in the succeeding year.

In addition to the attendance requirement, participation in the class discussions and assignments and achievement tests were used to measure progress.

The men who conducted the course were paid as

part-time instructors. The department head recommended candidates for instructors, and the men selected were trained, coached and supervised. One of the important by-products of the training program was the development of the instructor, for the teacher always learns more than the student.

At the end of each year, there was a graduation ceremony at which the manager of the plant spoke to the graduates, and the department head presented the certificates to the graduates. After the ceremony, a short social session took place. The employees who completed the 4-year program were presented with a diploma at a special dinner. A number of top management people spoke and met with the graduates on this occasion. The purpose of the training program was to help motor inspectors catch up and keep up with the technological progress in their field of work, especially electronics. They are in the top of the job progression so there was no job promotion possible. The only promotion possible was into supervision and that would be of interest to only a few. In such cases the training undoubtedly was a factor. However, the major reason for participation in the training program was expressed by one of the employees who said, "I do not mind being dumb about a lot of things, but I hate like heck being dumb about my own job, especially when I am at the top level of that job and, therefore, looked upon as a person that is supposed to know what he is doing."

John H. Greiner: On complex mill jobs which are saturated with electronic equipment a training program is established within our plant for a select group of customer employees, prior to shipment of the equipment. The instructors are all specialists who played a part in the designing and testing of the equipment.

The group first runs through a considerable number of sessions involving basic theory and then launches out into numerous sessions dealing with the circuits and equipment involved for this particular installation.

These programs are quite intensive and in some instances may require as many as seven days with six sessions per day. Even this liberal training is not the final answer. Also attending these sessions are the servicemen who will be assisting with the field work. This is very important because not only are these men brought up to date with new techniques, but they augment the factory program by demonstrating and answering questions on the job site which had not previously arisen.

John J. Timberlake: In a discussion of the training of maintenance personnel, there seemed to be general agreement on what was needed. The major problems in any program appear to be:

1. How does one create incentive?
2. What will the unions accept?

There are both volunteer and paid courses at the Middletown plant of Armco in addition to the usual paid apprentice courses. This paid program is an addition to the usual paid apprentice courses. This paid program is a qualifying program negotiated with our union. The curriculum is similar to that indicated by the author with several exceptions.

There is no rigid dividing line between electricians and mechanics in the operating maintenance groups. The men are called repairmen and are expected to meet all problems whether electrical or mechanical. The curriculum is therefore altered to include mechanics, hydraulics and special related subjects. Limitations on time require that some of the more advanced electrical courses, which are offered on a volunteer basis to graduates of our regular paid course, be deleted.

The first such courses were with highly selected groups. Recently only new men with a status approximating that of an apprentice have been trained. Future classes will be required of all new men in maintenance and will be offered to the older employees on a paid basis as rapidly as possible. A large number of courses are still conducted on a volunteer basis but there has been a definite decline in interest since the paid programs have started. ▲

CURRENT AISE DISTRICT SECTION MEETING NOTICES

COLORADO SECTION

Data not available

ST. LOUIS SECTION

Wednesday, September 20, 1961—Inspection Trip 7:00 P.M. (No dinner, no speaker)

Inspection Trip: New 22-In. Mill, Laclede Steel Co., Alton, Ill.

SAN FRANCISCO SECTION

Wednesday, September 20, 1961—Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Engineering Problems Overseas" by Ray Fullerton, Consultant, Kaiser Engineers International, Oakland, Calif.

Spenger's Fish Grotto, 1919 Fourth St. (Near University Ave.), Berkeley, Calif.

UTAH SECTION

Wednesday, September 13, 1961—Social Hour 6:30 P.M., Dinner 7:30 P.M., Meeting 8:30 P.M.

"Citizenship" by J. J. Eley, President, Public Affairs Consular Inc.

Grandview Cafe, Provo, Utah.

COMPUTERS

ONE reason for the eager competition in today's infant industrial computer market is that many suppliers have recognized the potential of computers as profit-making tools. They know that when computers prove their capabilities in pioneer installations, there will be a tremendous upturn in demand for computer installations by profit-minded user managements who will not wish to see their competition achieve cost advantages.

Another reason for the eager competition between suppliers is the fact that on the average three years are required to move from first planning to an operating computer installation. To be prepared for the expected upturn in demand, suppliers must enter the field now or find themselves with a 3-year handicap when their competitors obtain repeat orders on the basis of proved operating installations.

Moreover, the user group is concerned with similar considerations, since planning a computer control installation is a long-term process even when all hardware is available. The user who pioneers a successful installation can expect to enjoy the benefits of a long lead time of two to three years, while his competitors will have to start from scratch.

For these reasons, computer suppliers are currently investing very large sums in design of their products and leading steel companies and other users are investing time and money in pioneer installations from which they anticipate substantial returns.

Interest in the subject of automatic control by computer is high, because it is only in the last year or so that computer engineers have been able to demonstrate reliability of their products in obtaining consistent results. When electronic techniques are correctly applied, modern computers can reliably perform such tasks as:

1. Provide uniformity in control, by repeated reference to indelible information stored in memory, repeating the same action sequence.

2. Provide great speed in control, because of ability to manipulate information in milliseconds or even microseconds.

3. Do many things simultaneously, or at least so quickly in sequence that it appears simultaneous to an observer. This feature allows computers to keep track of everything, causing instant action to be taken when alarms occur, permitting greatly improved safety. There is no panic in a correctly designed control system, for it takes fail-safe emergency action.

4. The stored program digital computer can be provided with a comprehensive set of instructions. The instructions contain a complete plan of action and are stored in the memory of the computer where they are referred to by look-up procedures whenever needed.

5. A portion of these instructions may be devoted to self-checking, causing the computer to check its operation, with provision for automatic alarm on malfunction.

GENERAL-PURPOSE, DIGITAL COMPUTERS

In principle, any general-purpose, digital computer can do all of the things that any other general-purpose, digital computer can do. Such computers differ however in the speed with which they can accomplish a given task, the precision they can attain, the memory capacity or the maximum number of instructions that can be loaded into the computer at any one time, the reliability with which the task will be executed, the number of instructions required to accomplish that task, the programming ease or the relative degree of difficulty in composing the instruction list, the site requirements such as provision of air conditioning, false floors, etc., maintenance requirements and the sales price.

The range in these factors is such that the prices for general-purpose, digital computers vary over a wide range. Performance limitations are such that certain tasks cannot be handled by some computers at all because of speed or memory requirements, whereas other machines would not be utilized economically in a given task.

Coding—The cost of a computer system includes two important elements. One is the basic computer cost and the other is the programming cost: these are interrelated. A low-cost computer may be expensive to program and a high-cost computer may be relatively inexpensive to program. Obviously, the buyer should seek a machine which will achieve the best balance between these costs.

Therefore, it is appropriate to explore these matters further. A digital computer handles information in coded form. These codes appear as punch marks in punched cards, as holes in paper tape, as invisible magnetic recording on magnetic tapes, on the recording surface of magnetic drums or as the magnetic condition of individual cores in the magnetic core memory. Whether visible or not, numbers or alphabetic characters are encoded by assigning a number of code elements to each character to be encoded. These coded elements are often called "bits."

Bits are usually processed in groups called "words," and the number of bits per word is often called the "word length." When it is said that a computer has a word length of 24 bits, the basic information unit in the computer is 24 bits long. The number of bits per word determines the precision that can be obtained in arithmetical manipulations. For instance, a 24-bit word might be used either to encode a 4-digit decimal number, such as number 7692, or a 24-bit binary number, such as 110,001,110,000,100,110,001,100. Table I shows such a code.

Binary coding—In the conventional binary code, numbers are expressed as sums of powers of two, for instance: $15 = 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 8 + 4 + 2 + 1$; $9 = 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 8 + 0 + 0 + 1$. Instead of writing all the powers of two, we merely indicate whether a certain power of two was added or not to obtain the sum.

FOR INDUSTRIAL CONTROL

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. . . . proper application of the general purpose, digital computer requires explicit understanding of the functioning of the computer, the performance features of the individual computer being considered and the types of programs that the computer can accept successfully . . . .

Thus,

	2^5	2^4	2^3	2^2	2^1	2^0
15 =	0	0	1	1	1	1
9 =	0	0	1	0	0	1
61 =	1	1	1	1	0	1

Parity—When numbers are encoded in the binary form, the total number of 1's or 0's may be either even or odd depending on the particular information being encoded. An additional coding bit position can be provided and used as a check bit or as it is more commonly called, a parity bit, in the following manner. If the total of 1's in a word is odd, the check bit is made a 1. If the total of 1's in a word is even, the bit is made a 0. In that way, the grand total number of 1's in any word including the check bit will always be even. This so-called parity check is a very powerful tool for verifying the validity of coding in computers, and when one parity bit is provided per word, the computer has word parity.

Computer speed and word time—One basic measure of computer speed is "word time" which is the time required to do elementary processing of the information contained in a single computer word, such as adding it to another word, or storing it in the memory. The word time is determined jointly by the word length, which is the number of bits per word, and the bit rate, which defines how fast the bits are manipulated. For instance, a serial computer with a word length of 24 bits and a bit rate of one megacycle has a word time of 24 microseconds. A computer with a word length of 18 bits and a bit rate of 100,000 cps has a word time of 180 microseconds. Word time is one basic measure of computer speed.

Memory access time—Another important factor determining the effective speed of a computer is the memory access time. This time defines the time that elapses from the instant of first call for information from the memory, to the instant when it actually becomes available for processing. For instance, a magnetic tape has the disadvantage that you may have to unreel many feet of tape before you can locate a desired piece of information. Often, this may take several minutes access time.

Access time is often quoted as average access time on the assumption that on the average, you will spend half the maximum time for finding a desired piece of information. The random chance for finding a piece of information near the place where you start the search is as good as the chance of finding it at the other end of the reel. However, for control applications, the significant quantity is maximum access time because this defines how long you must wait in the worst case.

A magnetic drum memory is a rotating cylinder, having deposited on its surface a film capable of retaining magnetic recording. Stationary heads permit recording and playback of this information from fixed positions on the surface of the drum usually called "tracks." The access time of a magnetic drum depends on its rotational speed, and variations from 180 to three milliseconds are common. In special cases, it is possible to provide more than one recording or playback head per track, allowing the recording or playback of the information more than once per drum revolution with consequent reduction in access time. Such tracks are called "fast access" or "recirculating" tracks.

Random access memories—A core memory functions by storing single bits of information each in a core. Each stored word in a random access core memory is addressable through switching circuits so that there is never any waiting for access as in the case of the unreeling tape or the rotating drum. Typical access times for modern high-speed memories are from 0.5 to 30 microseconds, or up to 100 times faster than drums.

Processing speed—When addition of two numbers or the comparison of two pieces of information is considered, the time required to obtain this information from the memory should be included. Specifications that are quoted without access times are misleading because access times are normally many times as long as processing times. Also, for control computers, it is important that one consider maximum access time and not merely the average.

Instruction complement—Another important facet of computing speed is the instruction complement which is the list of operations that the computer can perform on command. Each instruction is a command for a specific operation. For instance, if the computer does

not have a multiply instruction, multiplication has to be effected by repeated addition, which may require many instructions that the programmer has to write out in order to obtain the equivalent of multiplication.

The more powerful the instructions of a computer, and the more there are of them, the greater will be the effective speed of the computer for a given word and access time. Another interesting aspect of this matter is that the more powerful and the more numerous are the instructions provided in a given machine, the less memory space will be used up in executing a given task since the storage of intermediate results and execution of multiple operations are largely avoided.

In a recent investigation, it was found that the elimination of several instructions in a trial computer design caused a 120 per cent increase in the memory-space requirement and increased the execution time very substantially for a certain application.

Because word time, the kind and size of memory and the nature and the number of instructions provided all have interacting effects on speed, there is still no single generally accepted yard stick for computer speed except that a fast word time, low access time and a powerful instruction complement are always beneficial.

Unfortunately, the hardware required to provide a fast word time, a random access, high-speed core memory and a powerful instruction complement is expensive; therefore, each designer is faced with a compromise between performance and cost.

Memory capacity—Apart from the access time capabilities of a memory, its capacity to store information (either in the form of instructions or data) is of vital concern because a computer can only do what it has been programmed to do by a list of instructions that was stored in the memory prior to turning the installation on. These instructions are usually typed out in code by a programmer and then punched out on paper tape or punched cards. Computers are provided with a paper tape or card reader device from which the instructions are transferred to the computer memory, where they are then stored for further use.

To accomplish a control job completely, all instructions pertaining to that particular job and all its ramifications must be in the computer's memory at all times. Typical control applications require from 200 to 20,000 instructions depending on the particular case. If any change or addition is made in the production process, additional instructions may be required. A computer which has a fixed maximum memory capacity of 4800 words is completely useless when the application requirements change to require 4900 words of storage. Another important aspect of memory capacity is interchangeability of storage locations for instructions and data. Where it is not possible to use a memory location for either data or instruction storage, very serious further application limitations may be encountered.

Because it is uneconomical to make provision only for maximum storage requirements, certain modern computers offer a wide range of memory options, making it possible to match the storage capacity exactly to the application on an economical basis, but providing for later expansion, if needed.

Because core memories with their decisive advantages are so much more expensive than drum memories, the most modern computers use a combination of these two types of memories in a way which combines the speed advantage of the core memory with the cost advantage of the magnetic drum memory.

Programming—Programming translates application requirements into computer instructions to be later transferred to the computer memory via punched paper tape or cards. The programming may be provided by the equipment supplier or by the user's personnel. The preparation of computer programs

TABLE I

Character Description	Symbol	Channel No. 7	6	5	4	3	2	1	Octal Equivalent
		Bit value P	2^5	2^4	2^3	2^2	2^1	2^0	
Blank		1	0	0	0	0	0	0	00
Space	—	0	0	0	0	0	0	1	01
Cross	+	0	0	0	0	0	1	0	02
Open parenthesis	(	1	0	0	0	0	1	1	03
Close parenthesis	)	0	0	0	0	1	0	0	04
Quotes	"	1	0	0	0	1	0	1	05
Colon	:	1	0	0	0	1	1	0	06
Dollars	$	0	0	0	0	1	1	1	07
Per cent	%	0	0	0	1	0	0	0	10
Semicolon	;	1	0	0	1	0	0	1	11
Ampersand	&	1	0	0	1	0	1	0	12
Apostrophe	'	0	0	0	1	0	1	1	13
Minus	⊖	1	0	0	1	1	0	0	14
Asterisk	*	0	0	0	1	1	0	1	15
Period	.	0	0	0	1	1	1	0	16
Carriage shift(cs)		1	0	0	1	1	1	1	17
Page change(pc)		0	0	1	0	0	0	0	20
Line shift(ls)		1	0	1	0	0	0	1	21
Slant	/	1	0	1	0	0	1	0	22
Zero (numeric)	0	0	0	1	0	0	1	1	23
One	1	1	0	1	0	1	0	0	24
Two	2	0	0	1	0	1	0	1	25
Three	3	0	0	1	0	1	1	0	26
Four	4	1	0	1	0	1	1	1	27
Five	5	1	0	1	1	0	0	0	30
Six	6	0	0	1	1	0	0	1	31
Seven	7	0	0	1	1	0	1	0	32
Eight	8	1	0	1	1	0	1	1	33
Nine	9	0	0	1	1	1	0	0	34
Comma	,	1	0	1	1	1	0	1	35
Number	#	1	0	1	1	1	1	0	36
Carriage normal		0	0	1	1	1	1	1	37
A	A	0	1	0	0	0	0	0	40
B	B	1	1	0	0	0	0	1	41
C	C	1	1	0	0	0	1	0	42
D	D	0	1	0	0	0	1	1	43
E	E	1	1	0	0	1	0	0	44
F	F	0	1	0	0	1	0	1	45
G	G	0	1	0	0	1	1	0	46
H	H	1	1	0	0	1	1	1	47
I	I	1	1	0	1	0	0	0	50
J	J	0	1	0	1	0	0	1	51
K	K	0	1	0	1	0	1	0	52
L	L	1	1	0	1	0	1	1	53
M	M	0	1	0	1	1	0	0	54
N	N	1	1	0	1	1	0	1	55
O	O	1	1	0	1	1	1	0	56
P	P	0	1	0	1	1	1	1	57
Q	Q	1	1	1	0	0	0	0	60
R	R	0	1	1	0	0	0	1	61
S	S	0	1	1	0	0	1	0	62
T	T	1	1	1	0	0	1	1	63
U	U	0	1	1	0	1	0	0	64
V	V	1	1	1	0	1	0	1	65
W	W	1	1	1	0	1	1	0	66
X	X	0	1	1	0	1	1	1	67
Y	Y	0	1	1	1	0	0	0	70
Z	Z	1	1	1	1	0	0	1	71
End file (ef)		1	1	1	1	0	1	0	72
End data (ed)		0	1	1	1	0	1	1	73
Item separator (iss)	●	1	1	1	1	1	0	0	74
End message (em)	>	0	1	1	1	1	0	1	75
Start message (sm)	<	0	1	1	1	1	1	0	76
		1	1	1	1	1	1	1	77

requires a thorough understanding of all of the application requirements, plus complete familiarity with computer operation. Because all possible contingencies must be envisaged in the preparation of a program, programming today is still as much of an art as it is a science. Programs prepared by different programmers designed to achieve the same results may differ by as much as two to one in the number of instructions and even more in the time required for execution. In control applications, it is necessary not only to provide for all possible combinations of situations that may arise, but also for correct timing including a determination of the safety margin, if any, which is available when a computer has been programmed to execute a required task in a prescribed time.

Programming a core memory is easier by an order of magnitude than programming a drum memory because the random access feature of the core memory avoids the necessity of laying out data and instructions in precisely the right sequence on the drum tracks to ensure that every word will appear at just the right place at the right time. This is called "minimum latency" or "optimum" or "minimum access" programming. Such programming, unfortunately, becomes impossible in control applications when there is no sure way of predicting the time of arrival of control information or when the need for control action will exist.

A most important matter is a computer's ability to treat relatively separate pieces of an over-all program as truly independent programs. Where such a feature of automatic program assignment and division exists, different portions of an over-all program may be written and later changed, if necessary, independently without affecting other portions of the over-all program that may already be correct. Where such a scheme of automatic program assignment and division (also sometimes called automatic program interrupt) is not provided, a change in any portion of an over-all program will affect many other portions of that program. This sets off a chain reaction that results in great expenditures of time in rewriting the entire instruction complement whenever there is a need to change any part of the program.

Call up of programs—Another aspect of the automatic program assignment feature of modern industrial computers is that specific programs can be automatically called up when needed. There is no need to run through hundreds of unnecessary program steps in sequence before acting on that portion of the program that is immediately needed, as occurs in computers not having the automatic assignment feature. The automatic program assignment feature permits high-speed access to any program part. By providing several levels of automatic program interrupt, the computer is able to give immediate attention to process matters to which high priority has been assigned and then handle matters of lower priority when time becomes available. For example, one can assign self-checking as a low priority so the machine will automatically check itself during any gaps of process control work which exceed 100 milliseconds.

Reliability—The factors affecting the reliability of computers are too numerous to discuss extensively. Among the most important factors are the basic

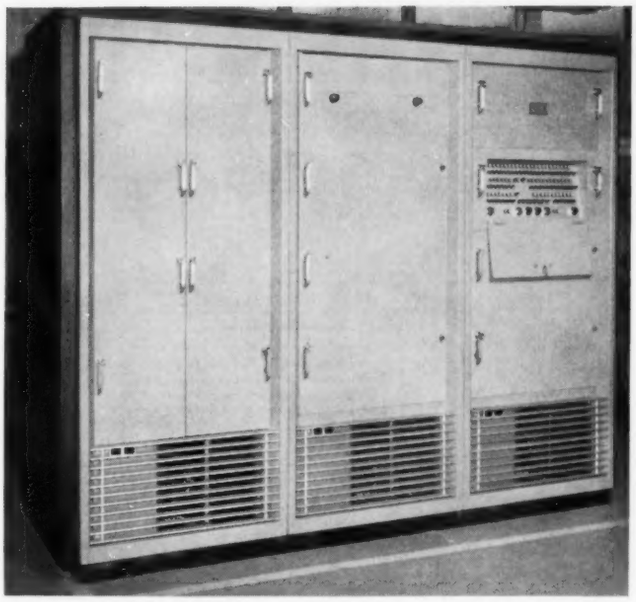

Figure 1 — The modern computer is a sealed self-cooled unit.

system concept and choice of coding, and the effectiveness of such self-checking methods as word parity, or performance of tasks in duplicate with comparison of results. In terms of hardware, it is now generally conceded that solid state devices when correctly applied are more reliable and consistent by several orders of magnitude than vacuum tubes and electromechanical devices. A profound effect on long-term reliability is exerted by the packaging of the equipment. It is vital that temperature excursions be kept within design limits since the reliability of transistors depends very strongly on their operating temperature. Also, the long-term effects of industrial atmosphere on circuit components has been found to be an important factor. If not properly controlled, it can cause irreversible deterioration of equipment over a period of time. Figure 1 shows an example of a modern industrial computer, packaged in racks that are sealed against dust and outside atmosphere and that have individual heat exchangers to recirculate and cool the internal cabinet air without intermixing it with the outside air.

Some confusion seems to exist with regard to the meaning of such concepts as "reliability," "maintainability," and "fail-safe" performance. A system may be entirely fail-safe but not at all reliable. It may be very reliable, statistically speaking, and yet expensive to maintain. It could be very maintainable and not at all fail-safe.

Reliability is measured in terms of consistent, correct performance and maintainability in terms of ease and required frequency of inspection and repair, both preventive and remedial necessary to achieve reliable performance. A determination of the consequences of failure (reliability merely measures relative frequency of failures) must be made before it can be asserted that the system is fail-safe. A further useful guide line is that the reliability of components can only be established over a period of time long enough to make statistical information meaningful. Assertions should not be based on very short term tests.

Certainly every user will insist on a fail-safe sys-

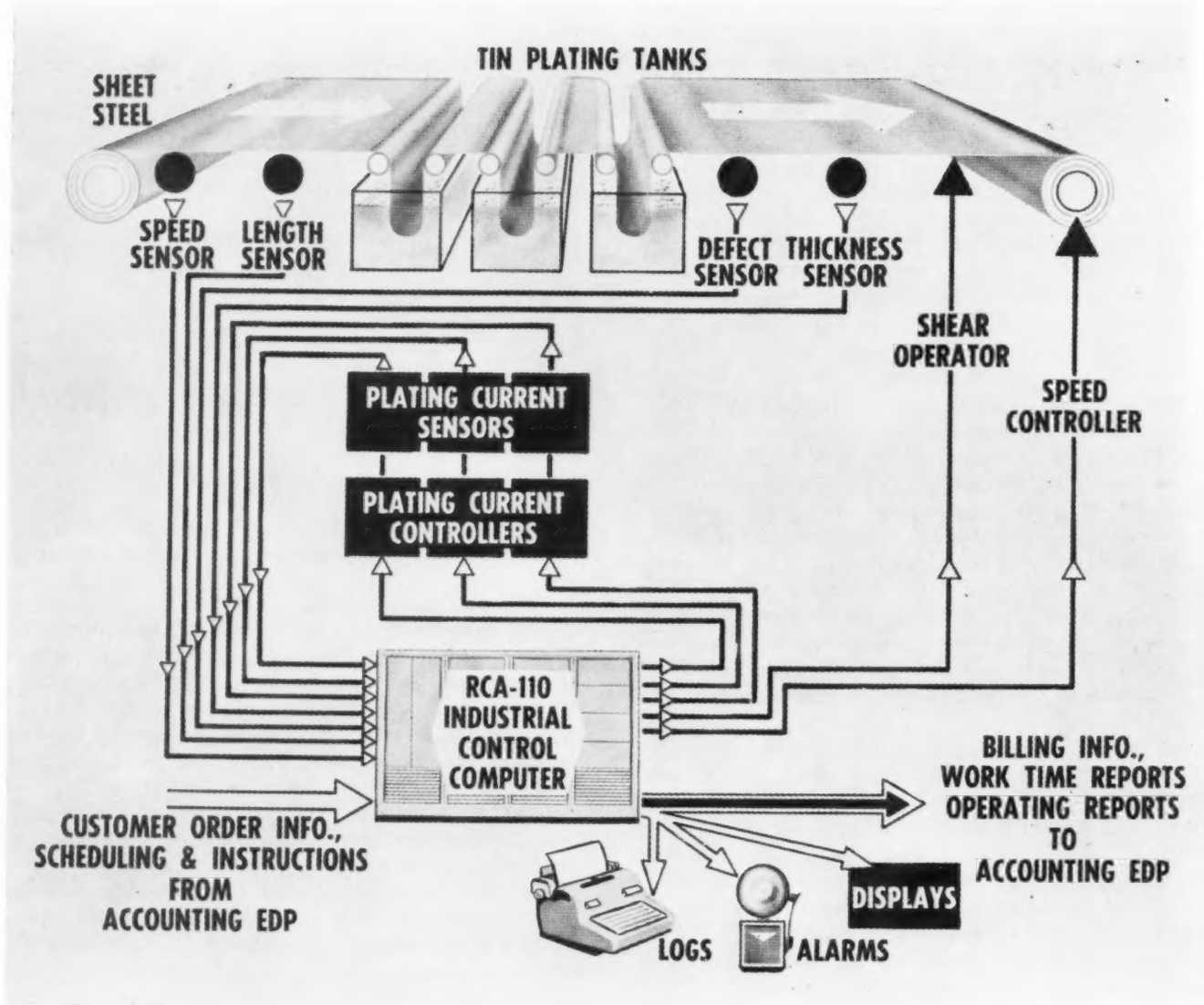

Figure 2 — The industrial computer must monitor many variables in production applications.

tems design, and this must include the computer plus what happens when a power failure occurs. Satisfactory fail-safe conditions can be achieved with automatic self-checking schemes for computer and system, and with nonvolatile computer memories and internal power supply capacity to permit sufficient carry-over for safe shutdown after the external power has failed.

RELATIONSHIP OF COMPUTER FEATURES TO APPLICATION

The foregoing discussion of computer features is merely an indication of the variety and complexity of computer equipment and performance features that must be considered in the choice for a specific application.

Different vendors of computers take different sales approaches: some stress low price, some stress high performance and others stress up-time guarantees. In the final analysis, only the user can decide the proper weighing of these factors. But, all of them should be evaluated before a purchase is made. Buying the least costly computer may become a very expensive mistake if it does not do the job.

Typical application—Consider as an example the application for a computer to an electrolytic tinning line as shown in Figure 2. Here a computer must keep track of several dozen, fast-changing variables, in addition to accepting its processing instructions in the form of punched cards and printing out complete records and reports regarding line utilization and crew performance, plus the printing of shipping tickets and product records. These concurrent, multiple tasks must be handled in such a way that the computer keeps up with production as it occurs. Moreover, the computer must have enough free time to provide such emergency control action as may be required, or to perform necessary self-checking of its operation, and, additionally, to allow for on-line maintenance in an application where it will be running 24 hr a day, seven days a week.

A basic fact in this particular application is that the steel may move at rates up to 3000 fpm and that basically all control is exerted on a per ft basis, and that all product shipping and billing records must be generated on a per ft basis. This may include classification of material in such categories as prime, mender and waste-waste.

A foot of material passes a given point approximately every 30 milliseconds. The computer must, therefore, have the ability to scan the input sensors, make the correct decisions, set up plating current and line speed to the proper value every 30 milliseconds, and have enough time left over to accumulate all of the source data for the reports that it has to print and for emergency action which may be required if, for instance, a plating current rectifier fails.

Timing—To determine whether the computer can do all of these concurrent tasks in the available time, a flow chart must be prepared which defines the individual decisions and computations that must be made to permit an accurate estimate of the number of instructions required. For instance, if this flow charting shows that 500 instructions are required every 30 milliseconds, this means that the execution time per instruction must not exceed 60 microseconds. Figure 3 is a portion of a flow chart.

The instruction execution time is usually one or two word times without memory access, but sometimes many word times, possibly up to 100 word times where access to a drum is required. An experienced programmer must check whether the required number of instructions can be executed in the available time. In addition to those instructions that must be executed every foot, there are many others to be executed only when the need arises. The total program may well be 2000 or 3000 instructions with the remaining instructions called up only on the occurrence of certain events such as a command to shear, or to print a certain report, or when an alarm is indicated. Timing out the program involves an understanding of the application, as well as good engineering and programming judgment to make a realistic analysis of how often these additional instructions will be needed and how quickly they will be needed. Certain infrequently called for instructions must be executed quickly when they are needed, and they must be kept ready for usage in a high-speed core memory. Only instructions for which waiting is permissible can be stored on a magnetic storage drum. Only after these additional factors are considered is it possible to determine the actual size of storage required.

Planning an installation—The most common mistake is to underestimate computer speed and memory size requirements, as any experienced computer manufacturer knows. The user has no way of evaluating the adequacy of a proposed computer for a given application unless:

1. He or his consultants have made an analysis to determine the computer speed and memory requirements.

2. Unless the manufacturer has made an analysis showing how many instructions are needed for program execution; how much time is available and required for task execution; and, what the storage requirements are. The user should obtain this information from the supplier before purchase.

Past experience has shown that substantial reserves, at least 30 per cent or more in computer speed, and substantial, unassigned computer memory space or capability for expansion are an absolute must in the initial specification of a computer for a control application. There are many instances on record where factors

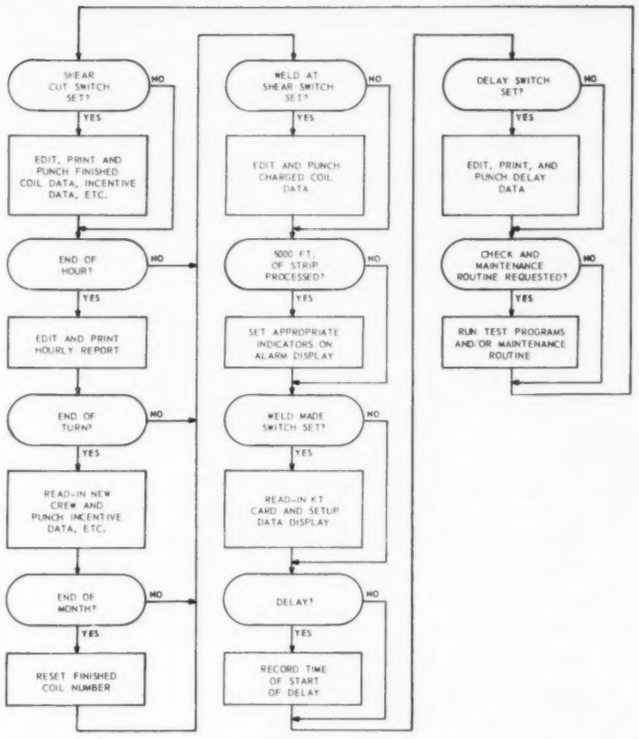

Figure 3 — Part of the flow charting gives an indication of the numerous instructions that a computer must have for accurate programming.

not appreciated at the time of a contract award, later came to light, causing abandonment of a proposed piece of equipment for the application. In a field expanding so rapidly as control by industrial computer, it is in the interest of the supplier as much as it is in the interest of the user to make sure that applications are planned to succeed. No one gains from the failure of any computer control installation.

Purchase specifications should therefore specify the performance that is required (leaving each supplier responsible to ensure that his equipment will, in effect, provide this performance) or specifications should be written in terms of equipment only where the user has made an exhaustive investigation of his own proving to his complete satisfaction that the specified equipment will in effect furnish the required performance.

Currently it takes about three years to go from first planning to an operating industrial computer operation. No single factor is more important in shortening this time cycle than complete understanding of the application and a clear definition of control objectives from the beginning. This requires the investment of money and time on the part of the user because his men must match the time and effort of consultants or suppliers who spend many years on application studies. No attitude is more injurious to growth of an industrial computer control than the naive belief propounded by a supplier and accepted by a user that a given general-purpose, digital computer can do everything without limitations. Only by a more detailed understanding of performance features such as those alluded to in this paper and their relation to performance requirements is it possible to plan and install industrial computer systems that are mutually

profitable. A convenient tool is a check list such as the following:

CHECK LIST

Basic Features

1. Is air conditioning required?
2. Are the cabinets sealed?
3. Are false floors and extensive ducting required?
4. Is the memory protected against power failure?
5. Is the machine solid state?
6. What reliability information is available?
7. Are the circuits standard production items? How many have been made? Whose transistor?
8. What is the heat dissipation margin of the circuits?

Memory

1. Does the machine have a core memory?
2. What is the core memory cycle time?
3. Does the machine have a drum memory?
4. What is the maximum access time to the drum memory?
5. Does the drum have fast access storage? How many tracks? How many words?
6. What is the minimum storage?
7. What is the maximum storage?
8. Can the memory be expanded after installation?
9. Are memory options program-compatible? (Are programs written for minimum memory usable for expanded memory?)

Machine Organization

1. What is the word length?
2. What is the word time, what is the clock rate?
3. What is the addition time, starting with a cleared accumulator and including access to add instruction, addend and augend, winding up with sum in accumulator?
4. How many built-in instructions are available?
5. How many variations per instructions?
6. How many index registers?
7. How many input/output devices can the machine handle? What are they?
8. Is parity provided?
9. Are there double precision instructions?
10. Does the machine have automatic program priority assignment?

Application

1. How many inputs?
2. How often must they be sampled? Specify each.
3. How many outputs?
4. How often must they be energized? Specify each.
5. What is included in main program?
6. How often must main program be executed?
7. How many instructions does man program take?
8. How much time is available for main program?
9. How much memory space (number of locations) is required for main program?
10. Has program been flow-charted?
11. Who did the programming?
12. Has an independent programmer checked these estimates?
13. What is the speed margin? (Estimate of available idle time of computer.)
14. What is the storage margin? (Estimate of available unused storage locations.)
15. Is word length adequate for required precision?
16. What method of self-checking is provided?
17. What protection against power failure is provided?

General

1. What maintenance and service arrangements are offered?
2. Is customer training provided? Where? How long?
3. What is spare parts availability?
4. What test equipment is necessary for maintenance?
5. Where can this machine be seen?

Discussion

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H. N. Snively: The author's paper has touched on many of the problems which face the steel industry on its entrance into the age of automation and computer control. Some of the points the author mentioned should be enlarged on.

Payout is an extremely slippery subject. Most control computer applications are being made to new line-drive and control equipments which are naturally more efficient and productive than their ancestors. No accumulated data over a long-time base is available for these processes. To deduce economic advantages from such installations is not significant. To measure the economic benefits from any one installation requires very thorough before and after analysis.

The digital control computer can both control and communicate. Both features can and should be used since costs are reduced and product saleability increased by improvements in both production and accounting services.

How much value is it to a steel company salesman to be able to show a customer that 95 per cent of his hot strip will be plus zero, minus one mil off-gage instead of plus five, minus two?

How much is it worth to receive a random request for ten tons of tin plate for delivery tomorrow, and to be able to say that it can be done?

These, and other benefits are real, but who can put a dollar value on them? Perhaps a joint engineering-economic study between the customer and supplier is the answer.

The design of any industrial control computer must be a compromise, not only between performance and cost but also between performance and reliability.

For example, for a given size memory (i.e., 32,000 words) magnetic core computer is several times faster, easier to program, and considerably more expensive than is a magnetic drum. However, the magnetic drum has one feature that makes it the best possible selection for on-line process computer control—reliability.

Programs stored in magnetic cores are vulnerable to accidental destruction. Data read from a core memory is destroyed in the process, and additional circuits must be provided to recreate the data in memory by automatically writing it back. During this read-write cycle, the possibility for creation of an error in the data exists; positive protection is not possible. In addition, because of the nature of core memory, transient signals caused by power failure, power interruption, or heavy inductive loads may destroy data in the core memory even though it is not in the process of being read by the computer. This results in unavailability of equipment during the time it takes to discover errors and correct them by reloading the original program. Program reloading is generally done by reading paper tape into the computer and may require two or three hr.

On the other hand, positive program protection is possible with magnetic drum memory because reading out is not a destructive process. The write amplifiers are physically disconnected from those portions of the drum containing program data, so it is impossible to accidentally alter this data.

Storage of the basic program, or executive routine, on a sheltered, nonvolatile area on the magnetic drum, and usage of a smaller core section for transient data and scratch pad calculations makes use of the best features of each storage technique.

The basic computer itself is only a portion of the over-all computer control system. It cannot by itself set voltages, or speeds, or positions, or temperatures. It must work through more conventional regulating systems by way of digital to analog converters, and in turn find out what is going on in the process through analog to digital converters. The additional control regulators and converters required to communicate with the process may be twice as expensive as the basic computer.

The system is no more reliable than its weakest element. Therefore, system reliability can be achieved only by selecting the highest quality regulating systems, sensing devices, typewriters, punches and other systems equipment. Again, reliability is directly related to simplicity. The peripheral equipment for unrelated functions should be kept to an absolute minimum. Every input signal and output action should be forced to justify its existence. It is better to provide space in the original design for later additions than to load up the system with functions and equipment of marginal utility.

A. C. Halter: The author discussed a large size computer handling a multiplicity of functions. However, is there not some tendency to use large computers, where it may be better to use a number of smaller units, each handling a portion of the total? It is realized that the economics may be in favor of a single unit, but unless two such units are used in parallel, any trouble in the computer would result in downtime of the process. Whereas, if individual units are used, one could possibly resort to manual control of a particular function until the computer trouble was located and repaired.

Another advantage of smaller units would be in the reduction of the long lead time required for the integrated system, and the greater flexibility in changing plans and future expansion.

Member: Undeniably, such factors as form of coding, parity and fault checking, computing speed, memory capacity and type, access time, etc., are of utmost importance. However, in considering the application of a computer, the most important factors by far are what is the process, how are its variables defined and how are these process variables related one to the other? No computer being considered for application can tell this, only know-how gained by experience with the process and study of the process can turn these facts into evidence. The prerequisite for computer application is intimate, detailed knowledge of process workings; the raw material and product characteristics, the machinery effecting the working of the product from its initial to final state, and the details of the complete electrical drive system that provides the motive power and includes the control and regulation and instrumentation that holds the process in practical limits.

Thus, the computer control must be fitted to the process, the process is not fitted to the computer control. The computer is not the process system itself; it is only an integral part of the over-all system. As such, the computer must be entirely compatible with the other parts of the integrated system, with the basic closed loop control and regulating components and circuitry of the electrical drive systems that have been evolved over many years as a result of experience obtained through intimate association with the processes. When a computer is applied to such an over-all system, much of its input will be derived from the basic control system and much of its output will be used in governing the basic control system's functioning.

R. W. Sonnenfeldt: The suggestion that a joint customer-supplier study might more definitely explore payout capabilities of computers is a good one and should be earnestly considered, and the comment that a computer design must also be a compromise between performance and reliability is generally valid. However, the statement that the magnetic drum is more reliable than a core memory is no longer in accord with modern experience. Both types of memories are used to exploit the advantages of each most economically. Most thoughtful computer designs of this year and next use both kinds of memory. Recent test data shows over-all reliability and availability of core memories superior to magnetic drum and disk memories. Also, modern core memories, unlike early office machine versions, are fully protected against loss of data through power interruption.

Modern system approaches have gone very far in assuring minimum downtime of any computer, large or small. The assumption that a number of smaller computers, each running vital portions of a total system, would in combination result in a more reliable system is highly debatable. Such a conjecture can only be verified against an actual situation but cannot be proved or debated in general.

A successful computer control system is an intimate union between process and computer. Mutual compatibility of process requirements and computer capabilities is vital to the success of that union. Thus, there is no antagonism between the statement of process requirements and the factors that must be taken into account when selecting a computer to translate process know-how into greater process profitability. ▲

Some New Design Features on a Rod and Merchant Mill

by WILLIAM R. LIEBEL, Assistant Sales Manager,
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Modern rod mill design can incorporate many features which add to mill availability and scope of mill product range.

WHEN this mill was in its development stage some years ago, machine designs were pointed out which had been in use for many years in Europe yet which were novel features in American steel mills. Particular reference is made in this instance to the skew roller type cooling bed which is part of the mill being discussed, see Figure 1. Later, during the discussions and when first quotations were submitted, the development of the combination horizontal-vertical finishing mill stands, which were finally included in the equipment to be erected in this new plant, had been started.

This mill is to produce about 50 to 70 tons per hr of mixed product, and the maximum finishing speeds of rod and coilers will be about 2300 fpm. The material to be produced will range from mild steel to high alloy and special spring steels. Rounds will be from $\frac{3}{8}$ to $1\frac{1}{2}$-in. diameter and flats from 2 to 4 in. in width with thicknesses from $\frac{1}{8}$ to $\frac{1}{2}$ in. For the spring steel flats, a special pack annealing feature is provided on the cooling bed. In addition, angles and channels up to three in. will be produced, along with several other custom-form sections.

This mill can be roughly divided into three parts: (1) the 4-stand billet rolling mill; (2) the continuous rod and merchant mill including repeaters and (3) the cooling bed and cold finishing end.

The starting sections are 4 x 4, 5 x 5 and 5 x 6 in., and these blooms will be about 16-ft long. They are delivered in bundles to an unscrambler from which they are fed singly over an approach table to the entry side of the heating furnace into which they are pushed by a furnace pusher.

At the delivery side, each bloom is ejected sideways by an ejector unit and is transported over a roller table to the 4-stand billet breakdown mills. The table contains a pushoff device with collecting pockets for rejects. Box-like steel castings are used for emptying the furnace.

The four 2-high breakdown mills for the production of billets have work rolls of 21-in. diameter and 40-in. length. Between the mill stands are located billet turners for upending the billets for the diamond passes. These billet turners are of a special design and consist of a lower and upper idle roller set in a circular frame which can be rotated by a hydraulic cylinder. With this same rotating movement, the upper roller is tilted in such a fashion that it acts like a self-adjusting clamping device for each size of billet being handled. The billet is always being held firmly against the live rollers of the roller table which connect the mills. The final billet sizes rolled on these mills are $2\frac{1}{2}$ x $2\frac{1}{2}$ in. to 4 x 4 in., and slabs 4 x 3 in. which represent the starting sections for the continuous merchant and rod mill following the reheating furnace.

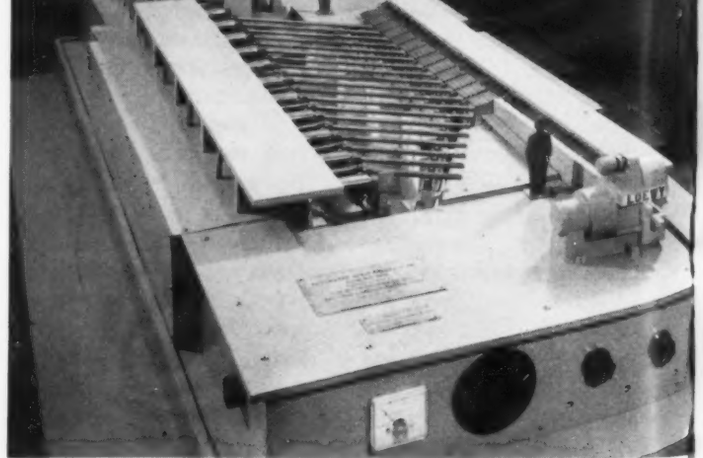
A runout table connects the last billet mill stand with the reheating furnace, and it contains a stationary shear with shear gage for cutting the billets into proper lengths of 36 ft for the reheating furnace. There is also a reject pushoff with cradles, an adjustable lineup device and a device which will push the billets into the furnace opening in conjuntion with a vertical pinch roll stand.

It should be mentioned that all operating mill tables contain rollers which are individually driven by flange type motors of special design and these motors are driven by available alternating-current.

The reheating furnace is side fed and the billets are pushed through the furnace by a water-cooled billet pusher located on the outside of the furnace. The distance between charge and discharge openings of this furnace is about 10 ft, and a swivel type ejector device pushes the fully heated billet out of the furnace sideways.

At the exit side of the reheating furnace and adjacent to the furnace opening, a pair of horizontal pinch rolls

Figure 1 — A model of the skew roller table shows the placement of the cut-to-length shear (foreground) and the structural shear.



are mounted. Positioned immediately behind them is a stationary shear which can cut billets to required lengths and, if necessary, also crop the front end. In the case of dividing the billet, the rear half can be returned to the furnace by means of the pinch rolls and an additional return pusher devicer of a new design. The runout table connecting with the continuous mills contains a reject mechanism and collecting pockets.

At the end of this runout table, a vertical edger is located to be used mainly for scale breaking or edge rolling in case of flat products.

Following the vertical edger are six horizontal mill stands with work rolls of a nominal diameter of 16 in. and 36-in. body length. The first three stands are driven by a 1200-hp motor through a common gear drive. The fourth stand is driven by its own 400-hp motor and stands No. 5 and 6 are again driven through a common gear drive by a motor of 1000 hp.

All these mill stands as well as the following 14-in. stands are mounted on sliding bases together with their respective spindles, spindle supports and pinion stands. These units can be shifted horizontally into exact pass line positions by means of hydraulic cylinders built into the sole plates. One spline shaft then connects the pinion stand with the gear drive. For rigidly locating the stands as well as the pinion housings, hydraulically operated clamps are provided.

Each mill screwdown is motor operated and the top roll balancing is effected by hydraulic cylinders built into the bottom chocks. Portable roll changing rigs can be removed when not in use.

Spare stands are provided, which are completely assembled in a work area, and can easily be exchanged with the operational stand. This is achieved by detaching a connecting hook between the pinion stand and the mill stand. The spindles are then held in position by a support stand during the change-over. For the different roll setting of the exchange mill, the support stand for the spindles can be preadjusted and, with the work rolls having been placed into a marked position, the assembly with the spindles is quickly accomplished.

Because of the variety of sections and products, quick change-overs are of the greatest importance. For this reason the design incorporates all the rapid change-over features with hydraulic connecting and disconnecting methods indicated.

All the mill rolls on the continuous section are mounted in tapered roller bearings, the 16-in. mills have straight necks and the 14 and 12-in. mills have tapered necks.

Close behind stand No. 6 is located a special design crop-end cobble shear of the rotary-swing type. This shear is synchronized with the last mill stand for front end cropping. In case of a cobble, the material can be cut into short pieces which will fall into crop disposal chutes. The lower knife of the shear is driven by a crank shaft and the material is parted on the upcut. The upper knife moves in a swinging arc and thus the front end of the material is being kept as straight as possible without bending. In order to compensate for slight differences in mill and cutting speeds, the whole shear system rests on a set of heavy springs which take up these speed differences.

The next four mill stands have work rolls of 14-in. diameter and 28-in. barrel length. Each is separately

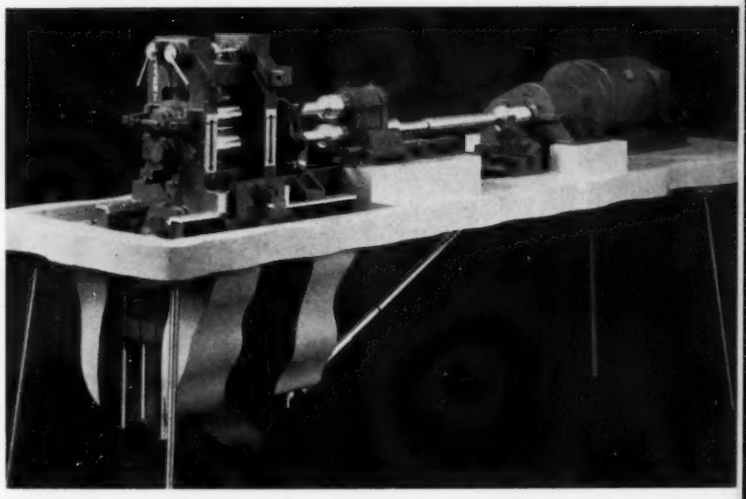


Figure 2 — The 12-in. stands can be operated as either horizontal or vertical mills.

driven by its own motor of 600 hp through gear drives, pinion stands and spindles.

The 14-in. stands, No. 8 and 9, are connected by troughs and an automatic repeater and so are the 14-in. stand, No. 10, and the 12-in. stand, No. 11. These repeaters are adjustable and adequate space is left for the loops to build up on the mill floor. These 14-in. stands are, except for size, identical in design to the 16-in. mill stands.

The finishing mills No. 11 through 14 are nominal 12-in. stands and are of special design incorporating many new features, see Figure 2. They are combination horizontal-vertical mills in which the main feature is the usage of each mill stand either as a horizontal mill or, by turning the stand 90 degrees, as a vertical mill, exactly on the same centerline and driven by the same main motor and gear drive.

Since all four mills are identical, they are interchangeable. Four complete spare stands are always on the assembly floor ready for instant exchange, either in the horizontal or in the vertical position. Therefore, the sequence of horizontal and vertical rolling in these last four stands can be varied and changed at will according to the pass program chosen.

When used as a horizontal mill, the rolls are connected by geared couplings and spindles to the horizontal pinion stand. Horizontal adjustment is achieved in a similar manner to the one described on the 16-in. mills.

By simply unclamping the stand and disconnecting all necessary parts, the mill stand can be lifted out and, when turned 90 degrees, can be inserted on the same location onto a vertical foundation slide which is adjustable up and down by means of motor driven spindles for lining up the pass with the adjoining mill stands.

In the vertical position, the drive end of the rolls is inserted into the vertical drive spindles situated in the foundations. These drive spindles are held in position by a similar support stand as mentioned before on the horizontal mills. They are preadjusted on the centerlines according to the vertical mill roll centers. These vertical spindles are connected at their lower ends to the pinion stand and gear drive which are permanently located in the lower end of the vertical adjustable foundation slide, see Figure 3. This lower gear drive con-

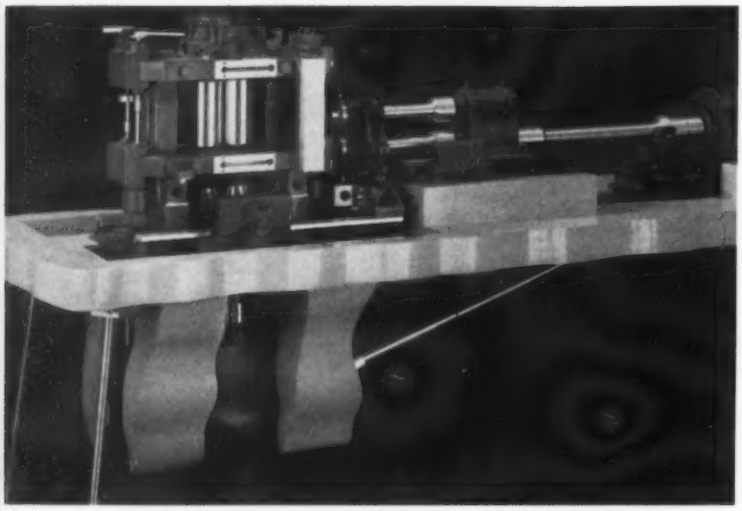


Figure 3 — The mill is rotated in a special device and then placed onto a vertical foundation slide which adjusts the pass line.

tains bevel gears which are connected through a slanting shaft to the bevel gears which are part of the main gear drive situated on floor level. Each of these main gear drives is connected to its own 800-hp motor. A special clutch arrangement disconnects that part of the drive automatically which is not being used.

The turning of the mill stand from horizontal to vertical is accomplished by simply lifting the complete mill stand off its sole plates by crane, inserting it into a special tilting device which is located on the assembly floor and, after turning this device 90 degrees, the mill is ready for reinsertion in the opposite way.

Vertical loopers with deflector rollers are located within the troughs connecting these finishing stands. A runout table guides the material into the high-speed rotary flying shear which is located in front of the cooling bed.

When the material is being coiled, it is guided through a selecting switch to the battery of pouring reels from where the finished coils are pushed onto an apron conveyor and then taken from a tilting device by a hook conveyor which is about 1500-ft long. The cooled coils, which can weigh up to 1200 lb, are then deposited on a turnstile collector from where they are taken off by truck for storage.

For straight finished product, the material runs out of the last finishing mill stands through the rotary high-speed shear where the front end is cropped. An automatic timing mechanism energizes the shear to cut the material automatically into cooling bed lengths calculated to multiple lengths of the total material available from each billet.

This shear is driven by a 40-hp motor in conjunction with a high-efficiency air-operated clutch built into the flywheel. Immediately after one cut, an air-operated brake goes into action to stop the shear at the correct angle. A 5-hp motor resets the shear by means of an electromagnetic clutch into its original starting position ready for the next cut. The complete cycle time for one cut is about 2.3 sec.

The comparatively short runout table behind the shear leads directly into the cooling bed which is a specialized design that has proved itself as excellent equipment for the cooling of rods and small sections made of higher alloys. This type of bed has been in operation in Europe for the last 30 years. The table is of the skew roller type, the action of which prevents the development of cold spots on the cooling material as it continuously changes its point of contact on the skew roller cooling surface. More material can be accommodated on this cooling surface than on other types of beds because the spacing between the material can be preselected according to its size. Also, the material can be deposited in groups for easier handling on the take-off side of the bed.

The total length of this cooling bed is 350 ft and the width between the centerlines of the runin and runout tables is 23 ft. Since the transport rollers in the runin table roll faster than the exit speed of the last mill stand the cutoff piece is pulled away, creating a gap of several ft by the time it arrives at the cooling bed. By lifting the material off the rollers, it comes to a stop by its own friction while the following material is automatically diverted into a side channel created by the lifted apron plates. This features permit the connecting table between shear and cooling bed to be kept to a minimum length.

Packs of spring steel material can be built up during the first cooling period, providing a gradual temperature reduction which eliminates precipitate cooling and, therefore, the hardening of the spring steel. This pack annealing equipment is designed to gradually dispose of the remaining packs (at the end of a pack annealing run) after which the bed is cleared and reset for any further usage.

By proper timing and correlation of the different lift-off and roller movements, groups of materials can be assembled on the cooling surface. As they gradually move across the bed each group can be lifted off and deposited on the runout table at the cool end of the bed.

All the drive mechanisms of the bed are automatically interlocked and adjustable. Altogether 12, 50-hp motors drive these mechanisms. The ingoing and outgling table rollers are driven by a-c flange motors, the speeds of which can be regulated by a-c frequency converters.

At the end of the cooling bed runout table, a disappearing stop can be used for roughly lining up the material group front ends before entering the cold 400-ton capacity structural shear. This is a downcut shear equipped with a flywheel and a one-revolution clutch, with the body of the shear set at an angle to the shear blade. Thus, the material after being cut, can be pushed off the table on the shear side without being moved away from the shear on the runout table, thereby eliminating an additional operation.

Behind the shear is a 65-ft long runout table with a shear gage mounted above. This gage is equipped with two motorized adjustable shear stop carriages. The kickoff mechanism built into the runout table pushes cut bars into collecting cradles which are situated sideways and parallel to this runout table. These cradles are mounted on a platform which is part of a weighing mechanism built into the foundations. Weighing and weight registering is done automatically.

As a complete separate unit, a roller straightener is supplied with a storage grid and a runin table, a runout table, a kickoff and a collecting grid. ▲

ARMCO AT BUTLER

LOGAN T. JOHNSTON
President

AR

by T. J. Ess

ARMCO'S Works at Butler, Pa., had its beginning as a wheelmaking plant in 1908, when the Forged Steel Wheel Co. first shipped railroad wheels manufactured from steel purchased on the outside. In 1910 an open hearth furnace was built and over the next few years, more open hearths and a slabbing mill were installed. The plant expanded into the production of hot and cold rolled sheets, and formed the Columbia Steel Co.

Columbia was among the first to place into operation a semi-continuous wide strip mill. This mill had many features which were incorporated in other hot strip mills later. It produced hot rolled coil down to No. 16 gage, in widths up to 36 in. Lighter product was made by cold rolling in coil form on 4-high cold mills. The plant also used continuous annealing and pickling equipment.

In 1927, Columbia Steel Co. and the Forged Steel Wheel Co. were merged into the American Rolling Mill Co. Since that time, Armco has developed the Butler Works into a specialty plant. It first shipped stainless strip in 1930, rolled from ingots shipped in from Middletown. The production of continuous galvanized strip began in 1936, with aluminized material coming in 1939 and electrical steels about the same time. In 1948 an electric arc furnace was installed, enabling the plant to make its own ingots in the stainless and high alloy grades.

Large expenditures over the years gave the Butler plant a new semi-continuous hot strip mill, new cold mills, a new wheel plant and expanded finishing facilities. The plant now has annual capacities of 485,000 tons of open hearth ingots and 74,000 tons of electric furnace ingots. Its principal products are sheet and strip steels in stainless, electric and coated carbon grades, as well as wrought steel wheels. It contributes considerably to the diversity of Armco.

The main plant (No. 1), with a total of 85½ acres, is very compact. It contains most of the production facilities, but has finally spilled over into No. 2 plant, which provides additional facilities for stainless finishing, and No. 3 plant, which is the wheel department, moved to make room for the new hot strip mill. The Butler Works normally employs 3750 people and is a major force in the industrial activity of the area.

OPEN HEARTH

Steel is made at Butler in basic open hearth furnaces and an electric arc furnace. There are six open hearths, each rated at 143 tons. They are 70 ft-6 in. long x 17 ft wide inside the steelwork and are built on 84-ft centers.

Hearths are 38 ft long x 14 ft wide, giving hearth areas of about 531 sq ft. Furnace bottoms are made up of 2½ in. of insulating concrete, 9 in. of basic brick and 9 in. of rammed basic material at the center of the furnace.

Furnace roofs are sprung arches of 12-in. silica brick with 15-in. ribs every fourth course. They have a span of 17 ft-9 in. at the center of the furnace, and a rise of 2 ft-6⅝ in. The roof is 39 ft-9¾ in. long between the knuckles. It is 5 ft-1 in. above the sill line at both front and backwalls.

The sloping backwalls are built up of basic brick topped by basic rammed material. Front walls, of 18-in. silica brick, have five doors 4 ft wide x 4 ft-6 in. high.

The furnace proportions provide areas of 105.3 sq ft above the bath at the center of the furnace, and 75.8 sq ft at the knuckles.

End walls are constructed of metal-cased basic brick. Ports and side walls are of silica brick. Two down-takes, 7 ft long x 4 ft-6¾ in. wide, at each end of the furnace provide an area of 63.8 sq ft. They lead to a single slag pocket 14 ft long x 13 ft-3 in. wide, built of fireclay brick with silica brick bulkheads.

AT BUTLER

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Chief Engineer
Armco Division

Regenerator chambers on each end of the furnace are 25 ft long x 24 ft-10 in. wide inside the brickwork, with flat suspended roofs. Checkerwork is built to depths varying from 10 ft-7½ in. to 13 ft giving about 7323 cu ft of checkerwork on each end of the furnace. Solid chimney checker flues are 7½ in. sq, using 9½ x 4½ x 3-in. brick.

Water-cooled concentric type burners introduce fuel oil and natural gas through the furnace ends. Over-all, oil makes up about 60 per cent of the fuel input, gas 40 per cent. Some oxygen is also introduced along the bottom of the burner to accelerate combustion, using about 1400 cu ft of oxygen per ton of steel.

Fuel oil is supplied to the open hearth through a circulating system with three 65-gpm pumps. Oil arrives at the plant in trucks, is unloaded by gravity and pumped into two 3,000,000-gal storage tanks. There are also two 10,000-gal service tanks. Oil temperature is maintained at 120 to 140 F in the tanks and boosted to 180 to 200 F by an individual heater at each furnace.

Each furnace is equipped with automatic reversal facilities, based on differential checker temperature. Meters measure fuel oil and natural gas input. Air for combustion is supplied to each furnace by a forced draft fan rated at 42,500 cfm, 8-in. water column. Each furnace also has another fan which discharges through a duct into a venturi throat about half way up the stack. This is to improve the induced draft set up by the stack.

Since the Butler plant has no blast furnace, the open

Six 143-ton basic open hearth furnaces provide an annual capacity for 485,000 tons of ingots.

Steel is poured into a variety of ingot molds, depending on its type and ultimate use.

hearth furnaces operate on cold charges. The proportions of scrap and pig iron are varied somewhat, depending on the desired carbon content of the heat, but average about 70 per cent scrap, 30 per cent pig iron.

Scrap consists principally of heavy melting, railroad, industrial bundles and turnings, originating in the area. Pig iron is of typical basic analysis; with 0.75/-1.20 per cent silicon, 1.5/2.0 per cent manganese and 0.025/0.04 per cent sulphur. The metallic charge totals about 334,000 lb per heat.

Open hearth charging is rather unusual in that a combination of conventional boxes and special cars is used. Ten high-sided cars, 33 ft-8 in. long and holding 100,000 lb of scrap each, and two special buggies carrying a chute mounted above three conventional charging boxes are used. The cars are loaded with scrap by magnet cranes in the stockhouse.

One or two scrap cars and one "chute buggy" are spotted in front of the furnace to be charged. An overhead magnet crane in the charging bay transfers scrap from the car to the chute, where the scrap drops into the charging box below. The box is emptied into the furnace by a conventional floor charger while the magnet crane is picking up more scrap from the car. Spillage is for the most part caught by the two boxes flanking the center box on the buggy. The adjacent boxes are emptied into the furnace as it becomes necessary. Also, the pans are exchanged every 10 or 15 cycles to prevent overheating. The method is particularly advantageous for light scrap. Some conventional charging cars and boxes are also used to complete the charge.

The charging method requires considerably less track space than the conventional method, relieving congestion and making it possible to load charges ahead. Also, as the charging machine does not have to disengage the peel after each pan, considerable time is saved.

Approximately 50 lb of raw limestone, 85 lb of burnt lime and four lb of fluorspar are used per ton of steel made. Alloy additions average 60 lb, deoxidizers 12.5 lb per ton. Deoxidizing is performed in the furnace ladle or mold, depending on the product and the condition of the heat. A furnace block of 15 per cent silicomanganese may be used on high-carbon heats. Aluminum might be used in the ladle or mold.

TABLE I
Open Hearth and Electric Furnace Buildings and Cranes

Building	Length, ft-in.	Width, ft-in.	Cranes		
			No.	Capacity, tons	Span, ft-in.
Stockyard	1050-0	84-0	4	10	80-5
Charging aisle	1050-0	78-0	1	30	74-6
			2	10	74-6
			2	7½	Floor
			1	5	Floor
Pouring aisle	924-0	60-0	2	200/25	54-1
			1	25	54-1
Mold building	525-0	82-7	1	10	80-5
			1	15	80-5
Stripper yard	231-0	82-7	1	200/15	80-5
			1	100	80-5

Fuel input usually ranges from 85,000,000 Btu per hr at the start of the heat to 63,000,000 Btu per hr toward the end of the heat, averaging about 70,000,000 Btu per hr. Fuel consumption runs 4,300,000 to 5,400,-000 Btu per ton of steel produced, depending on the grade of product. Oxygen for decarburization is introduced to the bath by pipes through the wicket holes. This use consumes about 100 cu ft per ton of steel. Recently, one furnace has been equipped with two oxygen roof jets.

Heat times may vary from 8 to 11 hr, depending on the product. Production is high for a cold-metal shop averaging 13.5 to 14 tons per furnace hr, or 25 to 26 tons per hr per 1000 sq ft of hearth area.

Steel is produced in low-carbon rimmed grades, in high carbons of 0.4 to 0.75 carbon, and in silicon grades of 1.0 to 5.0 per cent silicon. Normally, open hearth production runs about 65 per cent in the silicon grades. The rest is carbon steel, about half low-carbon, half high-carbon.

The heats, which average 143 tons, are tapped into 150-ton oval welded ladles. Silicon grades are reladled at one double or one single reladling stand, where the ferrosilicon is added.

Steel is poured into big-end-down molds measuring 18 x 35 in. and 20 in. x 30, 35, 40, 45, 50 or 55 in. and big-end-up molds of 21 x 38 in. or fluted rounds of 17, 22, 27 and 29 in. diameter. Before pouring, the interior of the ingot molds are sprayed with a pitch-base compound.

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Superintendent—Rolling

FRANK BURDETTE
Superintendent—Processing

E. M. NORTON
Superintendent—Plant No. 2

Slag flows into pots which are moved by rail to the dump, where it is processed by an outside contractor to recover metallics.

The use of oxygen for combustion and decarburization is said to give a 40 per cent increase in the production rate. High-purity oxygen is purchased from an on-site liquid air separation plant rated at 115 tons per day. Nitrogen from this plant is also used by Armco as furnace atmosphere in some annealing processed and for purging atmospheres out of some annealing furnaces.

The steelmaking facilities are housed in four adjacent aisles as enumerated in Table I. The stockyard has two railroad tracks at yard level and two elevated tracks at charging floor level. The pouring aisle has five pouring platforms each capable of accommodating one heat. The mold building and the unroofed stripper yard lie end-to-end.

This 19-ft electric arc furnace produces 70-ton heats of various grades of stainless steels. It has a 12,000-kva transformer.

Scrap and pig iron are unloaded in the stockyard by overhead crane. Limestone and ore are received in hopper cars and dumped from a trestle at the west end of the shop. They are reloaded from the ground by a small tractor shovel. Dolomite is dumped from railroad cars over a track hopper and elevated into an overhead bin. It is normally placed in the furnace by a dolomite machine. Ferrosilicon is received by trucks carrying weighed boxes from a storage area served by river barge. At the plant the boxes are handled by lift trucks and dumped as needed into large buckets which are used at the reladling stands. Industrial trucks are used extensively for handling miscellaneous materials in the open hearth.

ELECTRIC FURNACE

In 1948 an electric arc furnace was installed in the west end of the open hearth building, where it could be served by the existing open hearth cranes. It has its own 5-ton floor charger.

The furnace is of door-charge design with a welded shell $1\frac{1}{8}$ in. thick, 19 ft in diameter and 10 ft-6 in. high. Side walls are of two types of basic brick in checkerboard arrangement, $13\frac{1}{2}$ in. thick. They last about 120 heats. Roofs are of 70 per cent alumina brick, 12 in. thick, laid up in ring bond, without expansion joints. Roofs may last 50 to 80 heats.

The furnace is tilted by a 50-hp electric motor operating through reduction gearing, with the furnace tilting on toothed rockers riding on toothed rails.

The furnace has three graphite electrodes of 20-in. diameter. These are clamped in electrode arms supported in stationary vertical masts. The electrode arms are raised and lowered by electric motors working through gear reducers and cables. The $7\frac{1}{2}$-hp electrode motors operate under adjustable voltage control with rotating amplifier regulators. Electrode speeds up to five to ten fpm are available.

The furnace has a 3-phase 12,000-kva transformer with forced oil and forced water cooling. Primary voltage is 25,000, which may be connected in delta or wye. The delta-connected secondary has taps set to give voltages of 280, 235, 190, 162 and 136.

H. L. GADDIS
Superintendent—Wheel Works

H. R. MILLER
Superintendent—Maintenance

G. T. GILLIARD
Works Engineer

S. J. MacMULLAN
Works Metallurgist

Taps are changed on the high-voltage side by a motor-operated tap changer. The transformer has four per cent impedance. A 3-pole oil circuit breaker rated at 34.5 kv, 600 amp, is installed on the high-voltage side of the transformer.

Secondary current is carried from the transformer by air-cooled cables, each phase consisting of 32 cables, each of 1,750,000 circular mils.

An induction stirrer has been installed on the arc furnace. It is rated at 60 kw, 250-volt direct current and is driven at 30 to 60 rpm by a 150-hp, 460-rpm d-c motor.

A tight-fitting hood, applied to the furnace efficiently collects all smoke and fumes except that coming from door openings. The smoke is drawn away by a fan and passed through a water scrubber before being put through a stack to the atmosphere.

The furnace produces various grades of stainless steels, about 60 per cent being chrome-nickel grades and 40 per cent straight chrome grades.

It is charged with approximately 158,000 lb of cold materials. Heat time is about 7.0 hr, tap-to-tap, for a 70-ton heat, giving a production rate of 10 tons per furnace-hr. All of the heats are made using the double-slag process.

The furnace sets up a demand of about 14,500 kva. Power consumption averages 432.8 kwhr per ton of ingots. Steel is tapped into 100-ton ladles and poured into plug-bottom big-end-up ingot molds of the following sizes: 16 x 29 in., 20 x 31 in., 20 x 35 in., 21 x 39 in., 21 x 43 in., 21 x 47 in. and 20½ x 55 in.

Facilities for building furnace roofs and for ladle repairs are conveniently located near the arc furnace.

SLABBING MILL

Ingots coming to the slabbing mill from the open hearth first go to the stripper yard, 231 ft long x 82 ft-7 in. wide, served by a 200-ton stripper crane and a 100-ton stripper crane.

There are 22 soaking pits, arranged in six blocks. Four blocks have four regenerative pits each, 13 ft long x 5 ft-7 in. wide x 8 ft-2½ in. deep, of conventional reversing design. Another block has three one-way recuperative pits, 20 ft-1 in. long x 9 ft wide x 11 ft-6 in. deep, fired from both ends. One other block consists of three pits 24 ft-6 in. long x 7 ft-6 in. wide x 10 ft-6 in. deep, fired from one end with a hair pin flame travel.

The pits are fired with natural gas. Air for combustion in all pits is provided by eight fans. The air is preheated in the regenerators and recuperators to about 800 F. Automatic controls are applied to pit temperature, pit pressure and fuel-air ratio on the two blocks of recuperative pits. The regenerative pits are handled manually. Fuel consumption averages 1,400,000 Btu per ton.

Ingots are charged to the pits at temperatures ranging from atmospheric to 1700 F. Because of the nature of the operation, the proportion of cold ingots runs higher than in the majority of plants. Heating time for cold ingots runs 8 to 11 hr, depending on ingot size. Hot ingots may be heated in four to eight hr. Some stainless grades must be heated more slowly. A preheating pit is provided to put the initial heat into cold ingots of some high carbon and stainless grades.

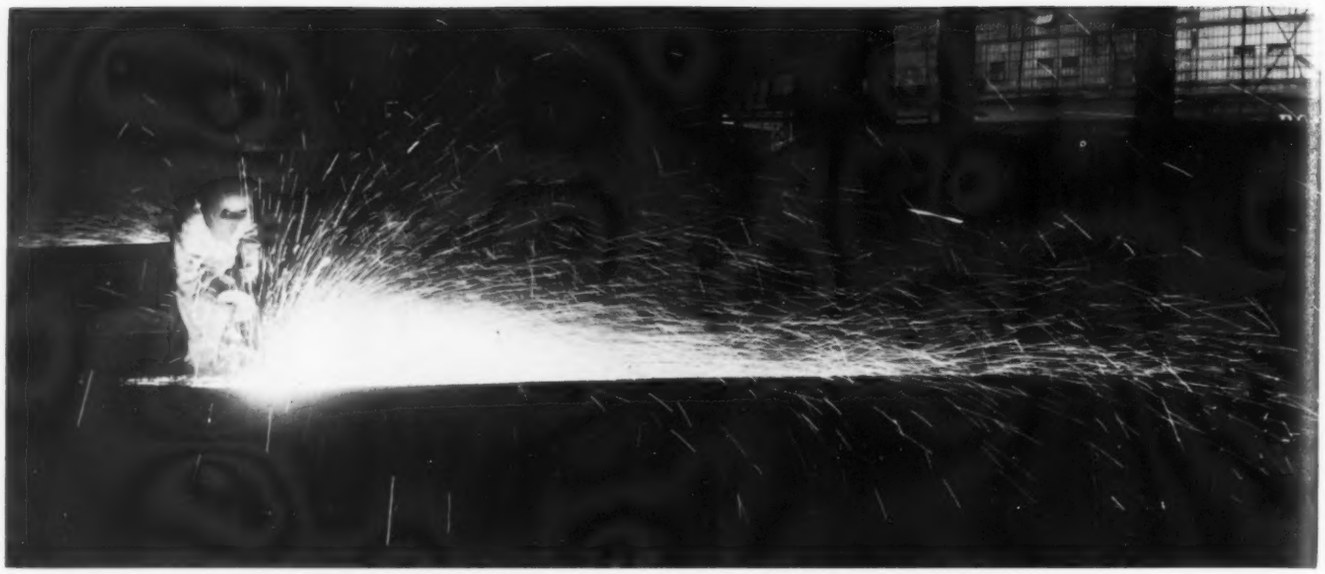
Ingots are charged into and drawn from the pits by two 10-ton pit cranes. The heated ingot is brought to the mill table by a self-propelled ingot buggy and proceeds over about 91 ft of tables to the mill.

The mill is a 2-high reversing, universal slabbing-blooming mill with two edgers. It is designed to roll slabs 13 to 52 in. wide x 4 to 8½ in. thick, and blooms from 8 x 8 in. to 12 x 12 in. Some sheet bar ¾ to 1¼ in. thick is also rolled.

Originally installed in 1909, the mill was rebuilt and widened in 1958. Cast alloy steel rolls, of 34¾-in. diameter x 56-in. body length, run in bronze bearings. The top roll is mechanically balanced by counterweights.

The top roll is moved up and down by two forged steel, single-threaded screws 10 in. in diameter x 1¾-in. pitch, driven by two 75-hp d-c motors operated under constant potential magnetic control. A maximum roll lift of 28½ in. is available. Roll lifting speed may range up to 90 in. per min.

The mill is driven through the two 17-in. spindles and pinions by a 7000-hp, 700-volt, 0/50/120-rpm d-c motor. The pinions are double helical, of 42-in. pitch



Carbon and silicon grades of steel are hand scarfed in slab form as needed to remove surface defects.

diameter and 7.33-in. circular pitch, 44-in. face and run in babbitted bearings.

The drive motor receives power from a motor-generator set consisting of two 3000-kw, 700-volt d-c generators, a 100,000-lb cast-steel flywheel 164 in. in diameter and a 5000-hp, 6600-volt, 356-rpm wound-rotor induction motor.

A pair of edging rolls is incorporated in the mill housing on each side of the horizontal rolls. They are located very close to the horizontal rolls and are driven through gearing by the main drive motor. Their opening adjustments are performed by electric motor in one direction, by hydraulic cylinder in the other direction.

At the mill entry, there is a hydraulically-operated pivot type manipulator. It is operated by a lifting cylinder of 16-in. bore, 24-in. stroke and two traverse cylinders of 13½-in. bore, 23½-in. stroke.

To improve the slab surface, descaling sprays are installed on the entry side of the slabbing mill. The sprays, which are manually operated, use water at 1000-psi pressure from two 500-gpm steam-driven pumps.

Ingots coming to the mill pass over three sections of approach table and the manipulator table, covering about 98 ft. These tables are driven through line shafts and mill motors under magnetic control. On the downstream side of the mill, four table sections reach to an 800-ton down-cut shear 135 ft beyond the mill. The shear is driven by a 225-hp, 600-rpm, 250-volt d-c motor, through a clutch actuated by a manually-operated hydraulic valve. A shear gage permits measuring sheared lengths of 4 to 18 ft.

Crops are pushed from the side of the shear table by a hydraulic plunger and drop into a crop car. The car can be pulled up an inclined track and dumped into a railroad car.

About 215 ft beyond the shear, a double-ram pusher moves slabs from the table on to an elevator piler, from where they are removed by overhead crane. Slabs are then moved by special flat cars to the hot strip mill. If they are ready for rolling they go to the strip mill slab yard. If conditioning is required, the slabs go to another area near the slab storage, where carbon and silicon grades are hand scarfed as needed. Stainless slabs are conditioned by grinding.

The performance of the slabbing mill varies considerably, depending on the product being rolled. With rolling speeds of 0/445/1068 fpm, the mill can roll as much as 260 tons per hr or 1225 tons per turn on silicon and mild steels. With these steels, a 20½-in. ingot might be reduced in nine passes. With some stainless grades, up to 29 passes might be required. Thus, the rolling rate drops to about 30 per cent of the rate for mild steels.

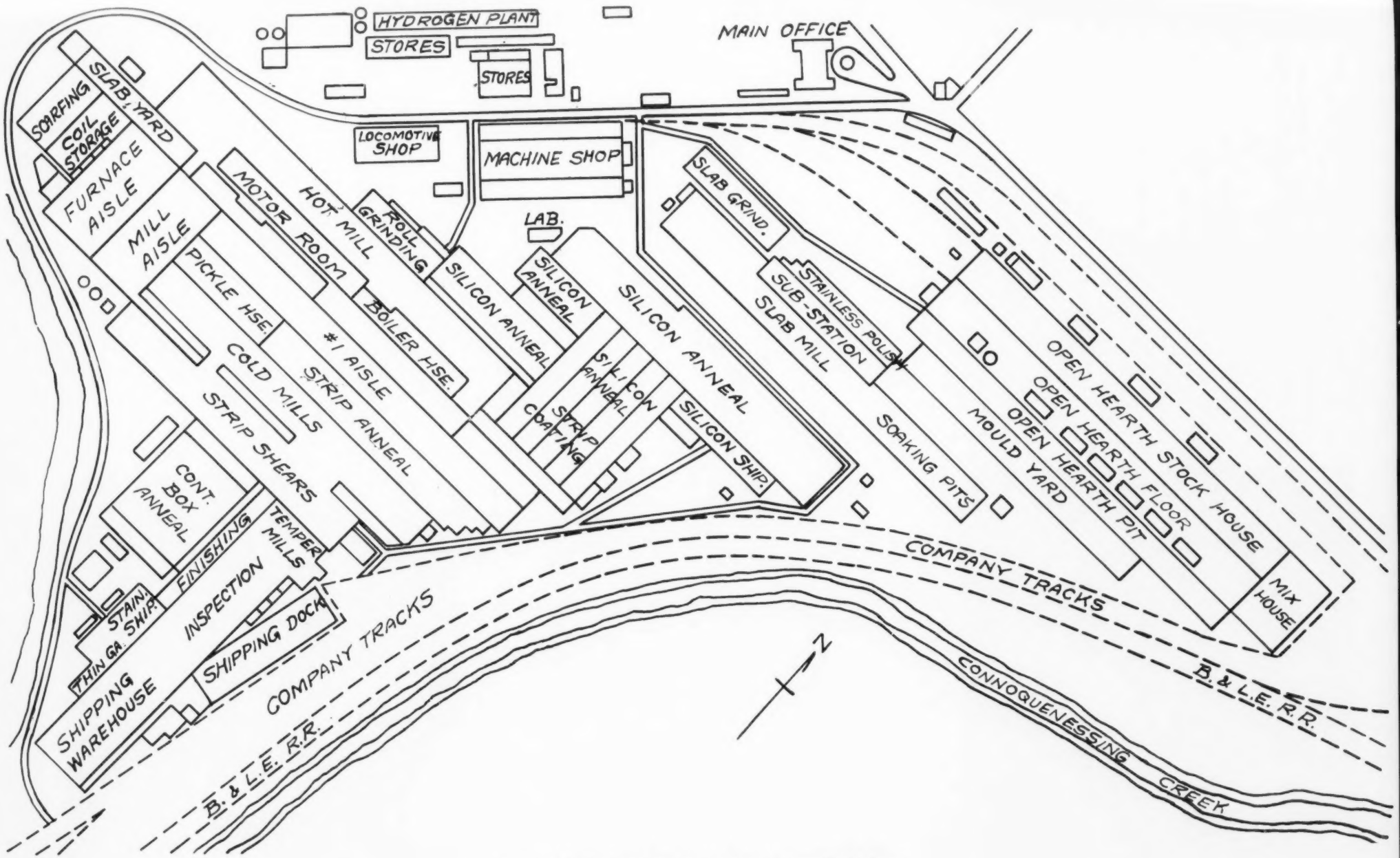
Also, some stainless ingots require intermediate reheating before the rolling can be completed. Such ingots are returned over the mill approach tables to the ingot buggy. A special motor-operated manipulator is installed in the approach table so that the ingot can be turned on edge to fit on the ingot car for the return trip to the pits.

Normally, the slabbing mill runs only two turns a day. The record monthly rolling is 55,000 tons, with an over-all rate of 125 tons per hr. Power consumption averages 78.8 kwhr per ton for the main drive, 24.3 kwhr per ton for auxiliaries.

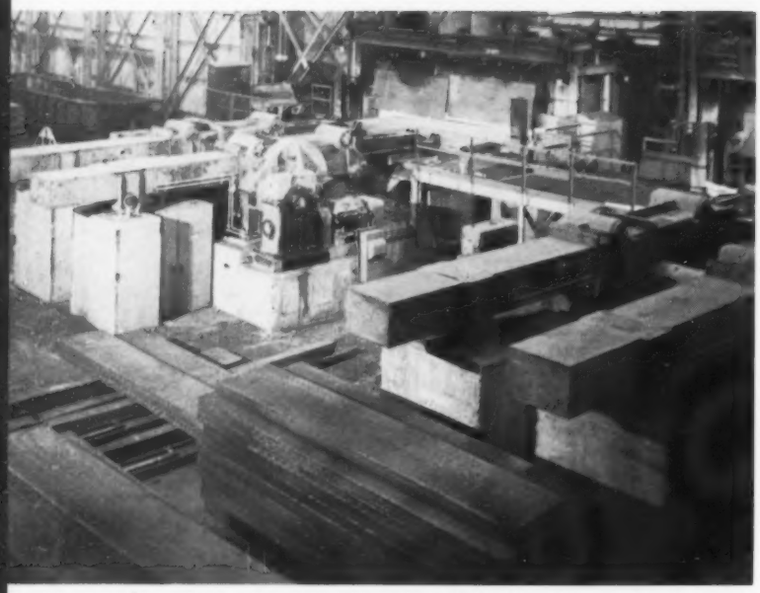
HOT STRIP

The original strip mill at Butler consisted of a 2-high, 27 x 48-in. reversing rougher and 165 ft away, four 4-high, 16 and 32 x 42-in. finishing stands on 22-ft centers, with loopers between. The rougher was driven by a 5000-hp, 0/150-rpm, d-c reversing motor. Each finishing stand was driven by a 2000-hp, 200/400-rpm d-c motor. Slabs, 2½ to 5 in. thick were given five or seven passes in the rougher and, at a thickness of ¼ to ½ in., passed on through the finishing train. The mill had a maximum delivery speed of over 900 fpm.

Outstanding was the fact that the mill was the first application of 4-high stands to continuous rolling, and



General layout of Butler No. 1 plant, Armco Steel Corp.



An overhead crane deposits slabs directly on the furnace skids for entry into the slab heating furnaces.

the first use of roller bearings on hot mill roll necks.

During its lifetime, the mill was rebuilt and modified several times.

In 1954 it was decided that a new hot mill was essential if the Butler plant was to be economically competitive. A thorough study was made to design a mill that would best handle the various grades of steel to be rolled. The result is a heavy semi-continuous mill with a 36½ x 58-in. scalebreaker, a 36½ and 54 x 58-in. reversing rougher with two edgers and five 25 and 54 x 58-in. finishing stands. The new mill started operations in 1957.

Slabs, ranging 13 to 50 in. in width, 3½ to 7½ in. in thickness, 13 ft-6 in. to 18 ft-6 in. in length and 9000 to 18,000 lb in weight, are brought one by one, from storage by overhead crane and placed directly on the furnace pusher skids. A double-head, rack-and-pinion pusher, with 15-ft stroke and 456,000-lb total thrust moves the slabs into and through each furnace. Each pusher is driven by two 75-hp mill-type motors.

Slabs for the hot strip mill are heated in three continuous heating furnaces with hearths 80 ft long x 21 ft wide.

There are three continuous, triple-fired slab heating furnaces. They are 89 ft-3 in. long over-all and have effective hearths 80 ft long x 21 ft wide. Through the first 60 ft of the hearth, slabs move over water-cooled skid pipes supported on refractory piers and anchored back to the pusher structure. The 20-ft soaking zone has a solid refractory hearth with mild steel skids.

The furnace is normally fired with natural gas, with oil as a standby. The top heating zone has six combination long-flame burners with a maximum input of 72,000,000 Btu per hr. Five burners in the bottom heating zone provide about the same input. The soaking zone is top-fired by eight burners totaling 48,000,000 Btu per hr input.

The furnaces have flat, suspended roofs nine in. thick, topped by two in. of insulation. Side walls are 13½ in. thick, backed with 3½ in. of insulation. Hearths consist of 18 in. of refractory and 4½ in. of insulation. The furnaces are steel-encased.

Air for combustion is supplied by a 40,000-cfm fan for each furnace. The air is not preheated. Each firing zone of each furnace is equipped with a fuel-input control and a fuel-air ratio control. Each furnace also has three temperature controls and a furnace pressure control, as well as totalizing meters on gas and oil.

Fuel input usually averages about 120,000,000 Btu per hr. Because of the various grades of steel that must be heated, heating rates run only about 40 tons per furnace hr, giving a fuel rate of 3,000,000 Btu per ton.

Actuated by the furnace pusher, the heated slab is discharged from the furnace, slides down skid plates to the dropout table and is moved to the mill.

The first stand of the mill (Table II) is a 2-high scalebreaker with rolls 36½ in. in diameter x 58-in. body length. Its 3000-hp drive enables it to take a relatively heavy draft, even on stainless steel. Roll adjustments are made through 14-in. mill screws of ½-in. pitch, driven by two 15-hp motors.

Next in line is a reversing universal roughing unit consisting of a 4-high stand with a vertical edger on both sides. The 7000-hp drive on the horizontal rolls and the two 600-hp edger drives are controlled from a single master switch in the pulpit.

The roughing unit draws power from a 4-unit motor-generator set consisting of two 3000-kw, 700-volt d-c generators, one 600-kw, 700-volt generator and a 9000-hp, 360-rpm, 6900-volt synchronous motor. The two 3000-kw units operate in parallel, differential and cross-connected cumulative series fields for load balance, to serve the 7000-hp motor. The 600-kw generator supplies the two 600-hp edger motors. Only one edger works at a time, as the vertical rolls on the exit side of the mill are pulled out of contact with the slab.

Horizontal roll adjustments are made by mill screws of 18-in. diameter, 1-in. pitch, driven by two 75-hp motors. A magnetic clutch permits separate or simultaneous operation of these screws. Hydraulic cylinders in the top and bottom backup roll chocks balance the top rolls. Maximum roll opening is 10 in. and a maximum lift speed of about 30-in. per min is available. Edger roll adjustments are made by a 50-hp motor on each stand.

TABLE II
Hot and Cold Strip Mills

Stand	Roll body length, in.	Roll diameter, in.		Distance from preceding stand, ft-in.	Motor data				Gear ratio	Roll, rpm	Roll face speed, fpm
		Work roll	Backup roll		Hp	Voltage	Type	Rpm			
Hot strip mill											
Scalebreaker	58	36½	...	...	3000	6600	Induction	510	24.4	20.9	200
Vertical edger	15	28	...	91-6	600	700	Shunt	150/450	3.04	49.3/147.9	362/1082
Reversing rougher	58	36½	54	7-9	7000	700	Shunt	40/100	Direct	40/100	377/942
Vertical edger	15	28	...	7-9	600	700	Shunt	150/450	3.04	49.3/147.9	362/1082
Finisher	58	25	54	206-0	5000	700	Shunt	125/250	2.72	45.7/91.5	300/600
Finisher	58	25	54	19-0	5000	700	Shunt	125/250	1.84	67.9/135.8	445/890
Finisher	58	25	54	19-0	5000	700	Shunt	95/190	Direct	95/190	622/1244
Finisher	58	25	54	19-0	4000	600	Shunt	125/250	Direct	125/250	820/1640
Finisher	58	25	54	19-0	4000	600	Shunt	140/310	Direct	140/310	917/2030
Tandem cold mill											
No. 1 stand	56	15½	49 x 54	...	(2) 1000	600	d-c	400/800	6.0	66.6/133.2	270/540
No. 2 stand	56	15½	49 x 54	13-0	(2) 1000	600	d-c	400/800	4.92	81.3/162.6	328/656
No. 3 stand	56	15½	49 x 54	13-0	(2) 1000	600	d-c	400/800	4.2	95.2/190.4	385/770
No. 4 stand	56	15½	49 x 54	13-0	(2) 1000	600	d-c	400/800	3.7	108/216	437/875
Single stand cold mills											
Reversing mill	42	15½	35½	...	1000	600	d-c	400/800	7.22	69.2/138.4	282/564
Reversing mill	43	16½	45	...	1500	600	d-c	300/600	2.46	122/244	500/1000
Reversing mill	42	16½	49	...	(2) 2750	700	d-c	250/490	Direct	250/490	1040/2000
Nonreversing mill	42	15½	32½	...	400	600	d-c	500/1000	14.27	35/70	140/280
Nonreversing mill	54	15½	35½	...	400	600	d-c	500/1000	13.36	37.4/74.8	152/304
Cluster mills											
Cold mill	41	2 3/16	...	...	1000	600	d-c	225/450	...	700/1400	400/800
Cold mill	17¼	1¼	...	...	150	230/375	d-c	300/1200	...	490/1150	190/760
Cold mill	54¼	2⅛	...	...	1750	750	d-c	225/400	...	680/1200	400/712
Temper mills											
Temper mill	56	35	...	...	250	250	d-c	350/1050	16.5	21.2/63.6	200/575
Temper mill	42	19¼	...	...	150	250	d-c	300/600	10.9	27.5/55	140/280
Temper mill*	58	26¾									
Temper mill*	58	26¾									
Temper mill*	58	26¾	...	...	300	230	a-c	585	19.15	30.5	236
Temper mill*	58	26¾									
Temper mill	24	16½	...	...	150	...	...	850/1200	2.22 8.4	45.6/63.4	196/270
Temper mill*	58	26¾	...	...							
Temper mill*	58	26¾	...	...	260	230	a-c	500	19.15	26	200
Temper mill*	58	26¾	...	...							
Temper mill*	58	26¾	...	...							
Temper mill*	58	26¾	...	...	300	230	a-c	585	19.15	30.5	236
Temper mill*	58	26¾	...	...							
Temper mill*	58	26¾	...	...							
Temper mill*	58	26¾	...	...	300	230	a-c	585	19.15	30.5	236
Temper mill*	58	26¾	...	...							

* Mills side by side. Common drive as indicated in motor column.

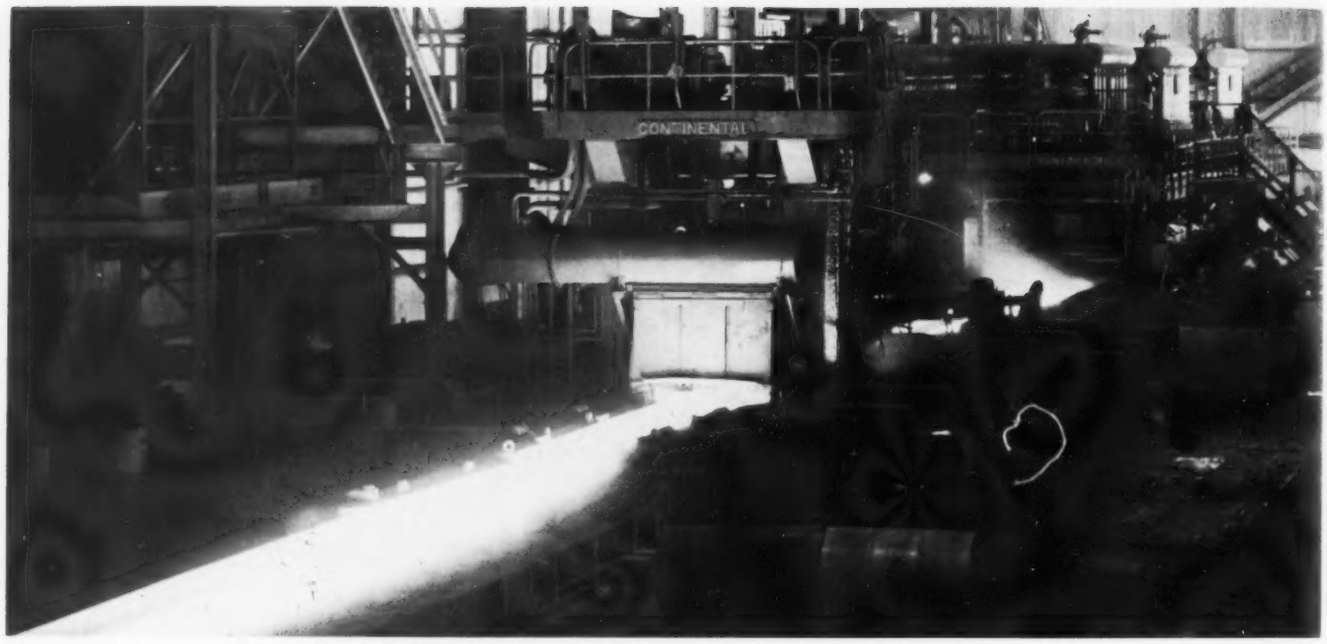
A preset control system is generally used to set horizontal roll openings, edger openings and side guard positions. Two schedule panels are located in the pulpit. One panel may be set up for the next order while the other panel is in operation. With this control, the operator merely presses a button prior to each pass. When the number of passes called for on the preset schedule has been completed, the adjustments return to the settings for No. 1 pass. The rougher can be scheduled for a maximum of 11 passes although the usual schedules use only five or seven passes. The unit can also be operated manually.

Leaving the rougher, steel passes over the runout table leading to an upcut dividing shear about 150 ft distant and a rotary crop shear 58 ft further. Both units are capable of cutting sections of hot chrome-nickel steel up to 1 in. thick x 52 in. wide.

The five finishing stands are located on 19-ft centers, with drives and speeds as shown in Table II. Mill screws on each stand are driven by two 75-hp motors, connected through a magnetic clutch.

All main drives of the finishing train draw power from three motor-generator sets. Two sets have two 4000-kw, 700-volt d-c generators, driven by an 11,200-hp, 300-rpm, 6900-volt synchronous motor. Each generator serves one of the first four finishing drives. The third set, which supplies No. 5 stand, consists of two 1500-kw, 600-volt d-c generators and a 4200-hp, 600-rpm 6600-volt synchronous motor.

Finisher drive speed may be varied by voltage output



The reversing universal roughing stand is driven by a 7000-hp motor and two 600-hp motors. In the background are the scalebreaker and heating furnaces.

of the generator and by motor field weakening. The five finisher drive motors can be controlled from a main master switch. Each motor also has an individual master switch and a vernier rheostat for speed adjustment.

Loopers, actuated by 50-hp d-c torque motors, are placed at the exit sides of the first four finishing stands to take up slack that may occur in the strip while rolling.

The mill is heavily designed in order to handle the tough grades of steel in the product mix. The reversing mill has housing posts of 899 sq in. cross section, the finishing stands, 877 sq in.

Roller bearings are applied to all roll necks, as well as in all pinion stands and gear sets.

To insure good surface on the rolled product, hydraulic sprays for descaling the strip are located, top and bottom, at the delivery side of the scalebreaker, on both sides of the rougher and at a set of pinch rolls preceding the finishing train. Sprays are operated by remote manual control. Water for the sprays is supplied by three 6-stage, 750-gpm, 1200-psi centrifugal pumps.

An unusual feature of the mill is the installation of fume-collecting hoods over the discharge sides of the roughing stand and the last three finishing stands. Each hood has a 15,000-cfm fan which draws the air through water-spray cleaning units.

Leaving the finishing train, strip proceeds over a runout table to two mandrel type downcoilers about 310 ft away. Each coiler consists of a pair of pinch rolls at table level, four pairs of blocker rolls and a collapsible mandrel. Pinch rolls are driven by two 100-hp motors, each pair of blocker rolls by a 30-hp motor, and the mandrel by a 300-hp motor, all 230-volt direct current. All of these motors draw power from two 7-unit 575-kw motor-generator sets driven by 2300-volt induction motors. Coiler speed is synchronized with mill speed by a signal from a pilot generator on the last finishing stand motor.

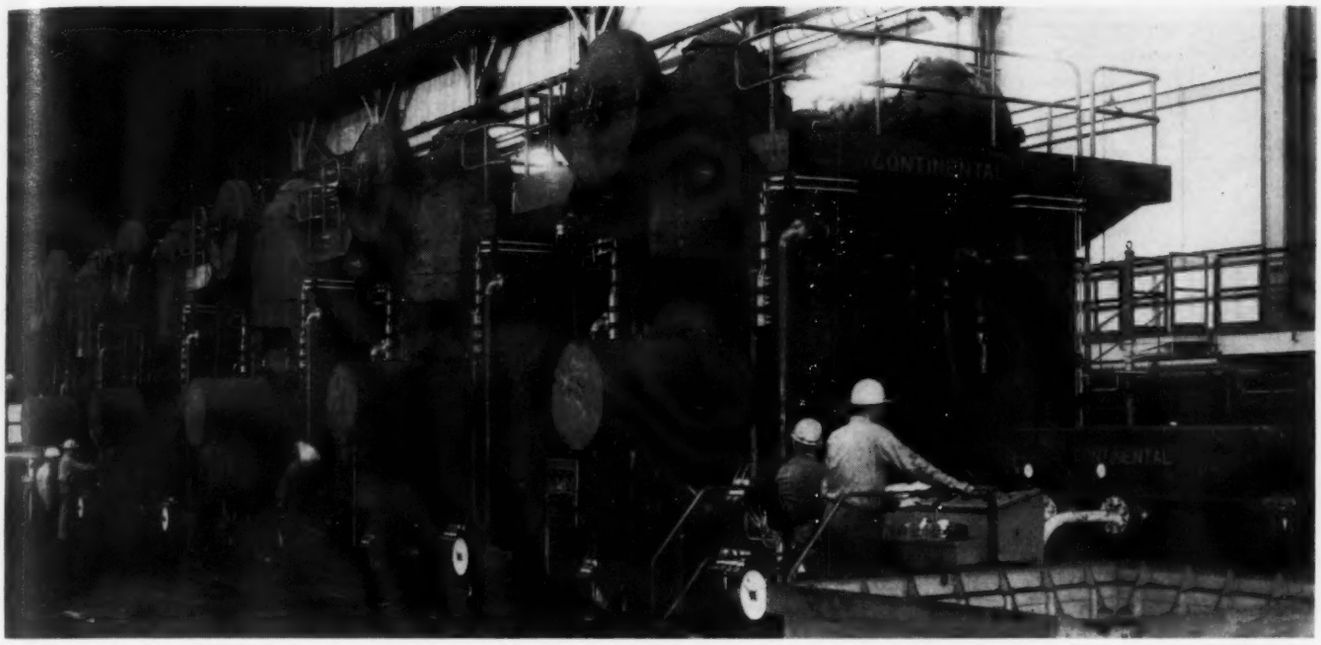
Coils are formed with 26-in. ID and 66-in. maximum OD.

An unloader at each coiler receives the coil and moves it to an upender, which in turn places the coil on a conveyor. The conveyor moves the coils underground from the coiler pit to another building and brings them up to floor elevation about 230 ft away, where they are banded, weighed and carried to adjacent storage areas.

Table III gives some details of the tables serving the hot strip mill. The tops of all table rolls are 2 ft-10½ in. above floor level and 1½ in. below the pass line. Tables serving the rougher are driven under adjustable-voltage control, tied in with the rougher through a pilot generator on the 7000-hp motor. Tables leading to the finishing train are also under adjustable-voltage control. The rougher runout and shear approach

TABLE III
Hot Strip Mill Table Data

Table	Length, ft-in.	Roll spacing, ft-in.	Roll		Speed, fpm	Drive, No. and hp
			Size, in.	Type		
Furnace dropout	106-0	2-0	14 x 58	Forged steel	340 maximum	(3) 50
Scalebreaker entry	27-6	2-0	14 x 58	Forged steel	340 maximum	(1) 50
Mill approach	40-0	2-6	15 x 58	Forged steel	375/950	(1) 100/200
Front mill	40-0	2-6	15 x 58	Forged steel	375/950	(1) 150
Back mill	44-6	2-6	15 x 58	Forged steel	375/950	(1) 150
Rougher runout	45-0	3-0	14 x 58	Forged steel	375/950	(1) 75
Shear approach	45-0	3-0	14 x 58	Forged steel	375/950	(1) 75
Finisher approach	51-0	3-0	14 x 58	Forged steel	375/950	(1) 75
Runout	288-11	1-6	12 x 60	Cast iron	2340 maximum	(192) 3



The hot strip finishing train, of five 4-high stands, has a maximum delivery speed of 2030 fpm.

tables are arranged so they may be operated with either the rougher or the finishing group, the transfer being actuated by a photo cell at each end of the shear table.

The runout table is designed in three sections, each served by a 200-kw generator. In normal operation, table speed is automatically matched with finishing mill delivery speed. Cooling water to the extent of 7325 gpm can be sprayed on the top and bottom of the strip for a 200-ft length of the runout table.

The hot mill is lubricated by seven circulating oil systems, seven automatic grease systems and one manual grease system. Some details of these systems follow:

Oil Systems

Equipment served	*Storage capacity, gal*	*Recirculation, gpm*
Scalebreaker pinions, drive and screwdown	1500	50
Mill tables and edgers	5000	75
Reversing mill and pinions	1500	50
Tables and shear	4500	145
Finishing pinions and screwdowns	4500	145
Finishing reduction gears	1000	30

Grease Systems

Equipment served	*No. of bearings*
Slab heating furnaces	66
Tables and side-guards	384
Scalebreaker, etc.	42
Edgers, feed rollers, etc.	154
Roughing screwdowns	4
Tables, shears, etc.	362
Finishing stands	407
Chutes, loopers and guides	66

The hot mill motor room, 483 ft long x 61 ft wide, houses all hot mill drives with their reduction gears, control equipment, switchgear and motor-generator sets. The 6900-volt switchgear, in 29 cubicles, contains two 2000-amp bus sections connected by a 2000-amp tie breaker, as well as the 6900-volt breakers for unit substations, lighting load centers and starting gear and control for the synchronous motor drives of the large motor-generator sets. All breakers have 500,000-kva, 6900-volt interrupting capacities.

Two 750-kw and one 1000-kw motor-generator sets supply 250-volt d-c power for auxiliaries.

A 3000-kva, 6900/2300-volt unit station in the motor room supplies power for descaling pumps, air compressors, etc.

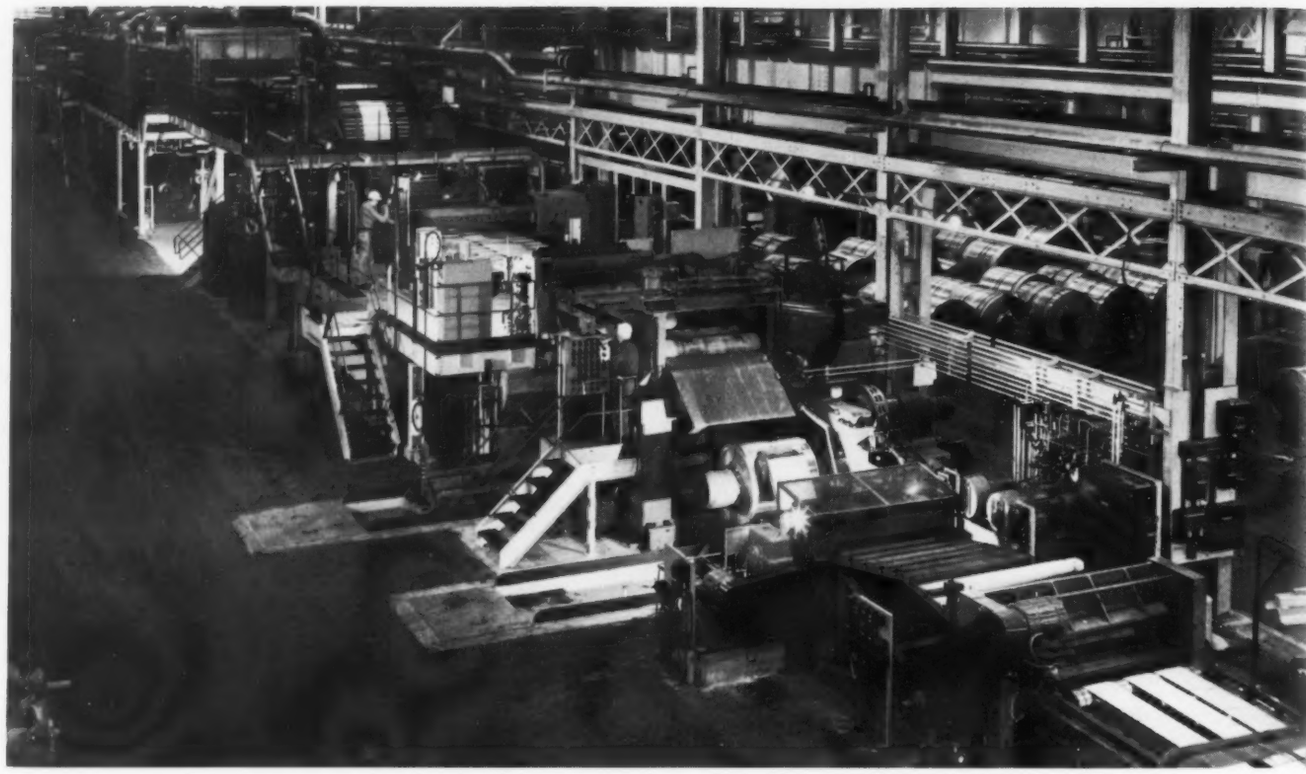
Auxiliary a-c power is supplied at 440 volts by four 1500-kva, 6900/460-volt unit substations located at consuming load centers.

Rotating equipment in the motor room is cooled by up-draft air from ventilating fans in the basement. Outside air is drawn through intakes on the roof and pulled through ducts to three oil bath filters, also in the basement. Louvers in the intakes and in the ducts permit adjustment of air flow for recirculation as desired. The 24 ventilating fans have a total capacity of 707,000 cfm at 1¾-in. water column pressure. Exhaust fans are also provided to remove warm air from the room as needed.

The hot mill and its auxiliaries use 368 motors totaling 28,730 hp, and 21 generators totaling 30,185 kw.

Hot rolled strip is produced in gages of 0.05 to 0.225 in. and widths up to 52 in. Rolling rates vary widely for the various grades of product, averaging about 150 tons per hr for carbon steel, 103 tons per hr on silicon steel, and 64 tons per hr on stainless grades. The monthly record is 45,200 tons, of which about ten per cent was stainless.

Power consumption of the hot mill per ton rolled averages about 90 kwhr for the main drives plus 18 kwhr for auxiliaries.



This new anneal and pickle line is used to process all grades of stainless steel in both intermediate and final gages.

PICKLING

Most of the hot rolled coils proceed to further processing and cold reduction in the Butler plant. Processing varies considerably with the type of product, and the nature of the equipment therefore departs somewhat from that found in the conventional strip mill. Briefly, these processes are:

Carbon steel—Conventional continuous pickling, cold reduction, aluminizing and temper rolling.

Silicon steel—Handled as carbon steel but perhaps with further special rolling and heat-treating techniques to obtain grain orientation.

Chrome-nickel steel—Continuous annealing, rapid cooling, pickling, cold reduction, continuous annealing and pickling, cold reduction, continuous annealing and pickling and temper rolling.

Chrome steels—Most of these grades are batch annealed at 1350 to 1500 F and slow cooled, followed by scalebreaking, pickling, cold reduction, continuous annealing and pickling and temper rolling.

There are six continuous anneal-pickle lines in the main plant. Table IV gives some data on these. It will be noticed that all of these contain an open annealing furnace, which is used only on the chrome, chrome-nickel and silicon steels. The furnaces are by-passed when the lines are used for carbon steels except for final annealing or normalizing for special purposes. Similarly, other parts of the lines may be by-passed

TABLE IV
Anneal—Pickle Lines

Unit	No. 2	No. 3	No. 4	No. 5	No. 7	No. 12
Over-all length, ft	915	915	700	700	390	925
Gages handled, in.	0.02/0.25	0.02/0.25	0.01/0.25	0.008/0.175	0.018/0.026	0.019/0.125
Maximum width, in.	39	39	51	39	36.5	52
Maximum coil weight, lb	12,000	20,000	12,000	12,000	20,000	33,000
Speed range, fpm	15/120	15/120	10/125	10/125	50/450	40/300
Tons per hr	10	10	9.5	5.5	24	45
Tons per month	6400	6400	6080	3520	12,800	22,400
Units in line	Uncoiler	Uncoiler	Uncoiler	Uncoiler	Uncoiler	Heater
	Welder	Welder	Welder	Welder	Shear	Uncoiler
	Furnace	Furnace	Furnace	Furnace	Welder	Welder
	Cooling hood	Cooling hood	Cooler	Cooler	Loop car	Leveler
	Pickle tanks	Pickle tanks	Sulphuric pickle tanks	Salt pickle	Furnace	Shear
	Scrubber	Scrubber	Electrolytic pickle tanks	Electrolytic pickle tank	Cooler	Loop car
	Dryer	Dryer	Nitric-hydrofluoric pickle tank	Nitric-hydrofluoric pickle tank	Pickle tank	Furnace
	Shear	Shear	Scrubber	Scrubber	Rinse	Grit blast
	Coiler	Coiler	Shear	Shear	Dryer	Pickle tanks
			Sheet trucks	Sheet trucks	Loop car	Loop car
			Coiler	Coiler	Side trimmer	Side trimmer
					Tension bridle	Tension bridle
					Coiler	Coiler

when the product does not require their particular function.

Chrome-nickel grades are annealed at temperatures of 1950 to 2050 F. When continuous annealing is used on straight chrome grades, temperatures run about 1450 F.

The pickling solution may range from 15 per cent sulphuric acid at about 160 F in the No. 1 and No. 2 tanks to a possible ten per cent nitric acid and four per cent hydrofluoric acid at 150 to 170 F in No. 3 tank.

No. 2 and 3 lines are generally used for the pickling of carbon steel and the annealing and pickling of silicon steel and iron. Lines No. 4 and 5 are used for the initial intermediate and final annealing and pickling of stainless steel.

Waste pickle solutions are neutralized with lime before being put into a sump.

COLD MILLS

The pickled coils are then ready for cold reduction, which is performed in a variety of mills listed in Table II.

A new unit in the Butler modernization program is a 56-in., 4-stand tandem cold reduction mill designed to roll pickled strip up to 50 in. wide. It will reduce stainless strip from gages of 0.15 in. down to 0.08 in., and silicon and carbon strip of 0.068 to 0.073 in. down to 0.018 in. Coils of 20-in. ID are handled with OD up to 74 in. Coils may weigh up to 1000 lb per in. of width, with a maximum weight of 33,000 lb.

The cast-steel mill housings, which were adapted from a previous mill, are of closed-top design. The two housings of each stand are tied together with top and bottom separators.

Work rolls of forged alloy steel run in roller bearings, as do the cast alloy steel backup rolls. Hydraulic cylinders in the bottom chocks balance the top chocks and rolls. An oil-hydraulic system serves all of these roll balances, as well as the roll changing rig.

Top rolls on each stand are moved up and down by two forged steel screws on each stand which are driven through worm gear reducers by two 50-hp d-c mill-type motors. A magnetic clutch permits operation of the screws separately or in unison.

Each stand is driven through a combination gear-reducer-pinion drive, with two 1000-hp motors connected to each unit. This unusual arrangement stems from the use of existing motors. It will also be noted that the rolling speeds of this mill are lower than conventional cold mills of today. This is due to the highly specialized products that must be rolled.

Roll coolant, a mixture of soluble oil and water, is supplied by a 1600-gpm recirculating system operating at 100-psi pressure. Spray headers at each stand deliver the coolant to the mill.

A fog exhaust system of 90,000-cfm capacity is provided for the mill stands and tension reel. It is a down-draft system with no ducts above the mill floor. Fog is sucked in by an exhaust fan and passes through a fog eliminator and an 80-ft exhaust stack.

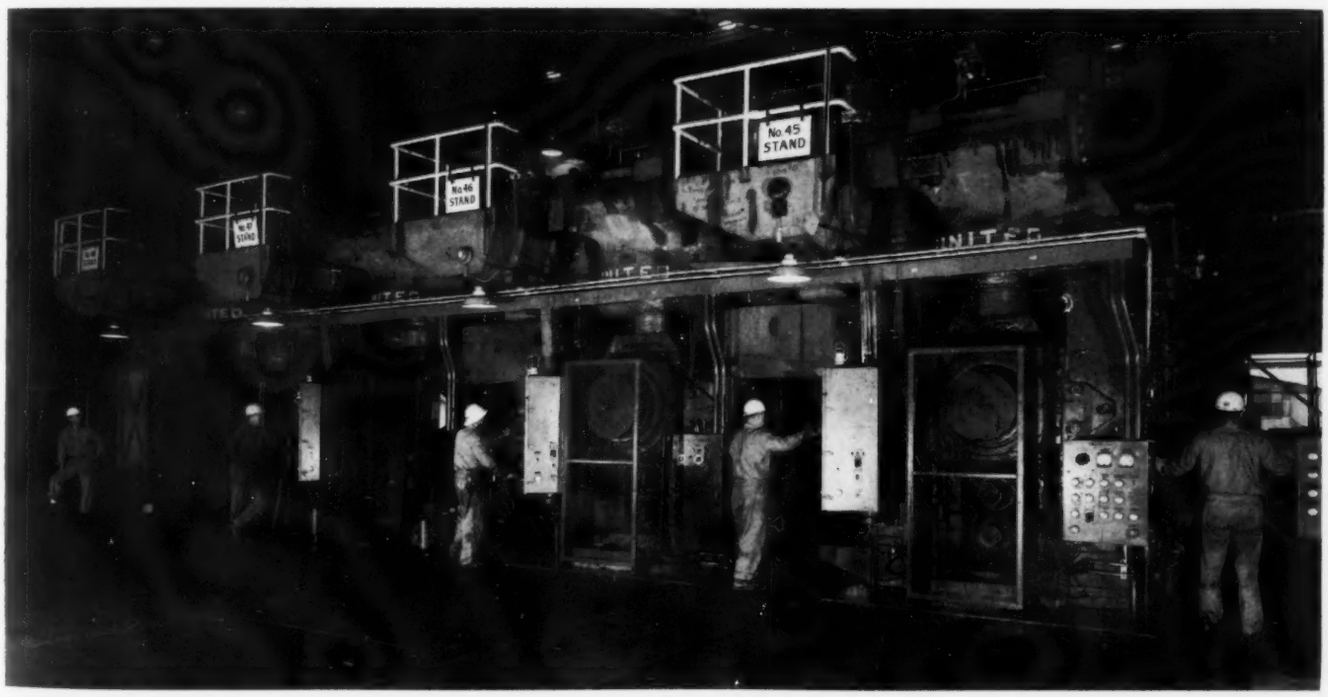
Coils coming to the mill are placed on a 2-strand chain conveyor which moves them to a coil charging car. One at a time, they are placed in the pay-off reel, which is connected to a 100-kw, 300/1200-rpm drag generator through a reduction gear of 11.84 ratio.

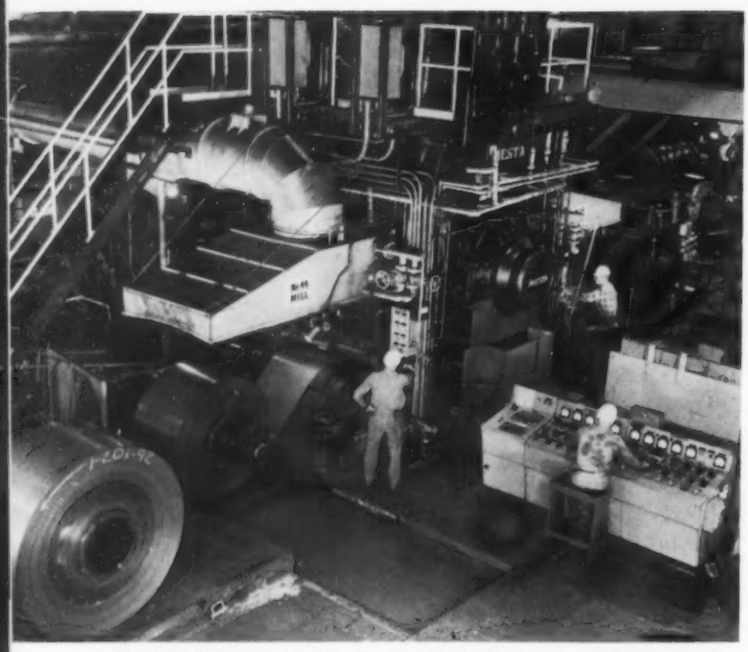
Before entering the mill, the strip passes through a 6-roll leveler driven by a 50-hp motor.

Leaving the mill, the strip passes over two deflecting rolls and on to a tension reel with hydraulically expanding and collapsing mandrel. A belt wrapper enters the leading end of the strip onto the reel. The reel is driven by a 1000-hp, 150/550-rpm 600-volt d-c motor through a 3.35:1 reduction gear.

The coil stripper and transfer car consists of a fork

This 56-in., 4-stand tandem cold mill rolls stainless, silicon and carbon grades. It is equipped with a flying micrometer and two X-ray thickness gages.





Cold rolling equipment also includes a number of single-stand units which are used at various stages of the finishing processes.

type cradle mounted on an elevator having an integral hydraulic cylinder. It removes the coil from the tension reel and places it on a 2-strand roller chain conveyor about 35 ft long.

X-ray gaging equipment is installed at the exit sides of No. 2 and No. 4 stands. The unit at No. 2 stand indicates strip thickness and may be used to control No. 2 stand screwdowns automatically. The unit at No. 4 stand indicates thickness and may also automatically control screwdowns and tension of No. 4 stand. A flying micrometer located on the exit side of No. 1 stand gives a measurement of strip thickness at that point.

The main drive motors of the mill operate under adjustable-voltage control, with power coming from two 4-unit motor-generator sets. One of these is a 3750-kw set driven by a 5400-hp, 6900-volt, 514-rpm synchronous motor. The other set is 5000-kw and is driven by a 5000-hp motor of similar characteristics.

The tandem mill and its auxiliaries are lubricated by one automatic grease system, two manually-operated centralized grease systems and one circulating oil system.

This unit is generally used for the initial reduction of all grades of product.

Cold reduction is also performed on three single-stand, 4-high reversing mills and three reversing cluster mills. There are two single-stand, 4-high mills used for break down cold rolling of stainless.

When cold rolling chrome-nickel steels, it is necessary to go to intermediate annealing and pickling for about every 50 per cent of total reduction made on the strip, on all except cluster mills. Reductions up to 75 per cent are possible on the cluster mills without intermediate annealing.

TEMPER MILLS

There are 16, 2-high mills, used principally for temper or skin-pass rolling. These are also listed in Table II.

A number of these have common drives as shown in the table.

Stainless steel may be further processed to obtain very high polished surfaces. This is done by seven belt-type polishing machines.

Throughout the entire processing of stainless steels, every care is taken to avoid damaging the surface. Any cause of scratches in the hot mill is eliminated. In the later stages of processing, paper is interleaved with the wraps of steel whenever the material is recoiled. In fact, about 125 lb of paper are used for every ton of stainless steel shipped.

Other finishing equipment includes three side trimmers, 12 slitters, two shearing lines, as well as stretcher levelers, roller levelers, resquaring shears, etc.

ANNEALING

A variety of annealing equipment is available in addition to the continuous lines previously mentioned.

There are three continuous tunnel type annealing furnaces, 192 ft long, 6 ft-9 in. wide and 9 ft-9 in. high, fired with natural gas through long-flame burners and high-pressure inspirating burners. Each furnace accommodates 12 cars, each carrying a lightweight batch annealing cover.

These units are used principally for the initial anneal of straight chrome grades and silicon steels. They operate at temperatures of 1050 to 1500 F, with cycles of approximately 24-hr heating, 24-hr soaking and 48-hr cooling. A box is discharged by pushing in a new box at the entry end. The discharged box is then carried to cooling racks paralleling the furnaces.

Material may be annealed in either coil form or sheet form. Each box may contain 5 to 30 tons, but the loading of adjacent boxes cannot be changed abruptly.

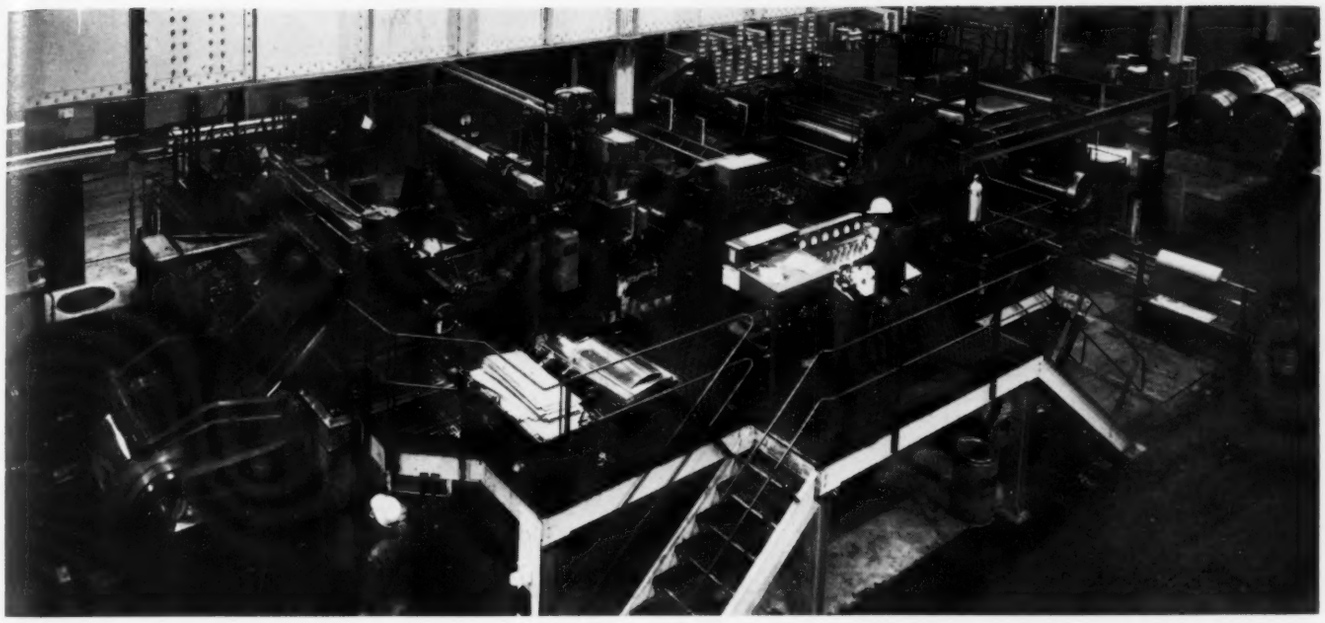
Three gas-fired portable cover annealing furnaces handle most of the magnetic iron processed in the plant.

There are also 66 electrically heated, resistance-type box annealing furnaces, used for the high-temperature annealing of silicon steel. These operate on 240-volt a-c power at temperatures ranging up to 2100 F. A hydrogen atmosphere produced at the electrolytic plant protects the surface of the steel during annealing.

COATING LINES

In 1937 Armco brought out a new continuous galvanizing process with coating adherence that withstands a high degree of forming or drawing without flaking. The process involves burning off the residual rolling oil, which also causes a thin oxide film to form on the steel surface. The oxide is then reduced in a dry, high-temperature atmosphere of hydrogen. As this temperature runs about 1700 F, the strip is simultaneously normalized. The heated strip then passes through the molten zinc bath and through cooling ducts.

The Butler plant has two of these continuous lines, but with the growth in demand for aluminum-coated sheets, they have been converted to aluminizing lines. The process is essentially the same except that a molten, slightly alloyed aluminum bath, held at 1250 to 1300 F, is used. The pot used for aluminum is of



Coils may be rewound on this line to put them on solid mandrels for further processing. The line may also be used to build up larger coils.

different construction than that used for zinc. Characteristics of the coating vary with temperature, time of immersion and rate of cooling. Coatings may range from 0.001 to 0.0015 in. in thickness. The lines handle widths of 37 to 49 in. at speeds of 65 to 80 fpm.

BRIGHT ANNEALING

In 1951 the Butler plant put in operation a bright annealing line (No. 10) which was intended primarily for the processing of thin gage strip; however, the potential for bright annealed stainless in the 300 and 400 series was recognized, and trial lots of type 430 were processed.

In 1956 a new bright anneal line (No. 18) was installed. This new line, which increases Butler's capacity for processing molding quality stainless, was designed to in. anneal 24 in. wide strip in gages from 0.010 to 0.050 and 16 in. wide in gages from 0.001 to 0.010 in. vs 0.001 to 0.050 in. in 16 in. wide strip on No. 10.

The bright annealing facilities have been modified several times. Although many changes have been made, these two lines are similar in many respects to conventional annealing lines, consisting of uncoiler, welder, burn-off cleaner, controlled-atmosphere, gas-fired muffle furnace, cooling hood and coiler.

WHEEL PLANT

Wheels, which were the basis of the original plant, are now made in a new plant (No. 3) completed in 1956. Steel for wheels comes from the open hearths in No. 1 plant in the form of fluted round, hot topped ingot, 17 and 22 in. in diameter.

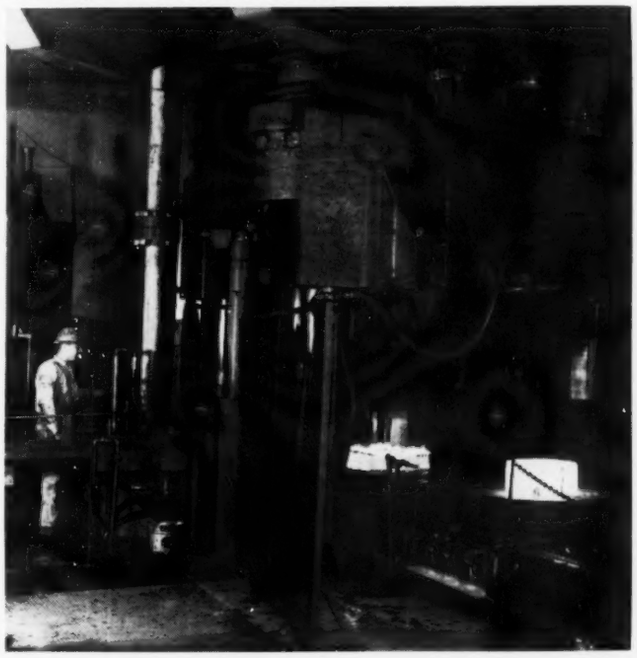
At the wheel works, ingots are first "notched" in special lathes which cut them into blanks of sizes appropriate to the wheel sizes to be made, leaving, however, about five in. at the center. The notched ingot is then broken into separate blanks in a 125-ton press.

Blanks are heated and soaked in a gas-fired rotary hearth furnace under automatic control. One by one, the blanks are discharged from the furnace and carried by an automatically controlled car through high pressure descaling sprays to a 6000-ton forging press. With interchangeable dies, this press first upsets the blank to a round slab about five in. thick, then in a second operation the rim section, web section and hub section are formed. Next, the blank is moved to an 800-ton punch press, where the bore is punched out.

The next unit in the production line is a horizontal wheel mill, wherein the tread and flange section and the plate section, are rolled simultaneously. Finally, the wheel is moved to a dishing press for final shaping and stenciling.

After controlled cooling to about 1000 F on a hook

Heated steel blanks are first forged into round slabs in the first step of wheel manufacture.



After piercing and rolling, the wheel is then dished and stenciled.

conveyor, the wheels are held at 1100 F for 4 to 16 hr to relieve stress. They are then cooled, inspected and turned in special lathes which machine the flanges, treads and hub faces. The wheels are then rough bored on a specially designed boring mill.

The wheel plant also contains heat treating equipment so that wheels may be quenched and drawn. It is possible by differential heating to vary the hardness of the wheel from hub to rim, so that the hub is soft enough to be machined easily, the web is tough to resist stress and the rim is hard for wear resistance.

After a final inspection, the wheels are ready for shipment.

In a normal month, the wheel plant will produce about 4000 tons of wheels.

UTILITIES AND SERVICES

All electrical power for the Butler plant is purchased at 25,000 volts, 60 cycles from the utility company serving the district. At the steel plant, power is distributed at this voltage over five principal circuits. One circuit runs to the open hearth and slab mill area where a 15,000-kva bank of transformers reduce the voltage to 6900. A second circuit goes to the electric arc furnace where the furnace transformer is 12,000 kva. Another circuit runs to the electric box anneal dept., where ten transformers totaling 5500 kva reduce the voltage to 240. Two circuits run to a substation in the strip mill area, one going to a 15,000-kva, 25,000/2900-volt bank of transformers, which, principally serve the cold mills. The other circuit, leading to a 25,000-kva, 25,000/6900-volt transformer bank, serves the new hot strip mill. Cooling fans permit the last two banks to be operated at 35 to 50 per cent higher capacities.

At No. 3 plant, there is a 10,000-kva, 25,000/7200-volt transformer bank, while a 5000-kva, 25,000/2300-volt unit serves the wheel plant.

With full operations, the entire Butler plant consumes 30,000,000 to 34,000,000 kwhr per month on a demand of 60,000 to 62,000 kva.

Steam is used only for processing, space heating, oil heating and oil atomizing. It is supplied at 150-psi pressure and 480 F by two 15,000-lb per hr, gas-fired boilers and five 50,000-lb per hr boilers fired with coal on underfeed stokers.

Because Connoquenessing Creek, the primary water source for the plant, is a small stream, water conservation through recirculation has been developed to a high degree. Three 3000-gpm pumps move water from the creek to an interceptor pit or to a reservoir. Four vertical pumps rated at 3000 gpm each boost the water from the interceptor pit to a clarifier where solids are removed. Four more 3000-gpm pumps pump into the main plant distribution lines.

At the open hearth a closed system with cooling tower recirculates water for furnace cooling. Water from the slabbing mill is returned back to the interceptor pit. At the hot strip mill, furnace cooling is provided by a closed recirculating system with a cooling tower. Water from the roughing unit flows to a scale settling pit, from where it is recirculated. Scale is removed by chain conveyor and put into railroad cars. From the finishing train, water flows back to the interceptor pit. The water from the runout sprays is provided from another closed system without cooling facilities. Two other closed recirculating systems, each with a cooling tower, serve the pickling, annealing and coating departments. About 5000 gpm are drawn from the creek as make-up for the entire system.

Some water is also purchased from the municipal system for sanitary purposes, for boiler feed and for No. 2 and 3 plants.

After controlled cooling and heat treating, a specially designed lathe machines the wheel's flange, tread and hub face.

Maintenance work and a small amount of construction work is carried on in the battery of well-equipped shops usually found in steel plants. Mill rolls are cared for by a 60 x 186-in. roll lathe and eight roll grinders ranging in size from 10 x 72 in. to 60 x 216 in. The roll grinders are located in various areas so as to most conveniently serve the various mills.

NO. 2 PLANT

General—In 1956, the property of the American Bantam Car Co. was purchased. This is located about 1½ miles from No. 1 plant and nearly adjacent to No. 3 plant.

The property has a total area of 17½ acres with five acres under roof. The main building is 180 ft by 700 ft and has four aisles. Adjacent is a fifth aisle 80 by 380 ft and a railroad shipping track. A truck loading dock is under roof in one end of aisle four of the main building.

Several auxiliary buildings serve the facility. These are principally: a plant office annex, a boiler and compressor house, a water treatment building, a pump house, a supply warehouse, a receiving and storage warehouse and a guard and clock house. In addition, the engineering dept. for the Butler Works occupies the old office building located on the property near the main building.

The plant is equipped to process all grades of stainless steel in the intermediate and final stages of processing. The first annealing, pickling and rolling is done at No. 1 plant. The coils are then delivered to the No. 2 plant by truck for finish processing, grinding, rolling, slitting, shearing and shipping.

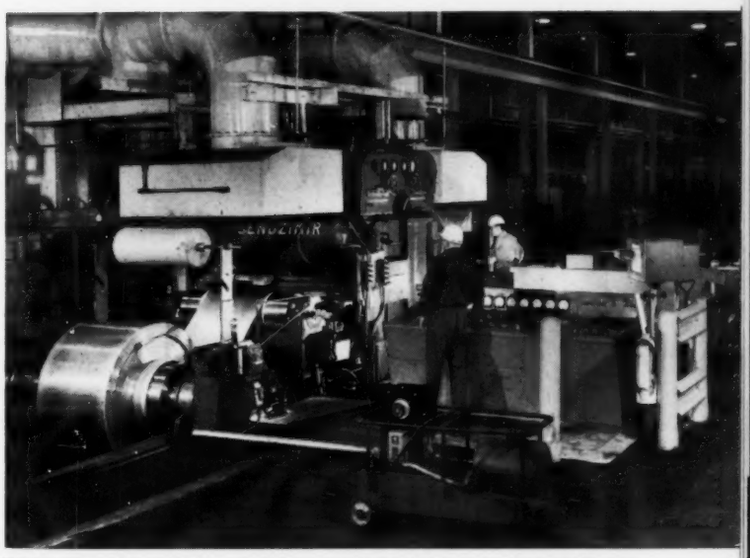
Annealing and pickling—An anneal and pickle line processes all grades of stainless in both intermediate and final gages. The line is approximately 480 ft long and consists essentially of 30,000-lb capacity terminal equipment, two open-type catenary furnaces for annealing and scaling, a molten salt descaler bath, electrolytic pickling and regular pickling. The line is designed for 0.010 to 0.080-in. gage, 24 to 52-in. widths, at speeds up to 150 fpm in the processing sections. Coils are brought to and taken away from the line by ram-type lift trucks.

In order that the line may run continuously in the processing section, strip storage is provided in looping pits. A double loop at the entry end of the line provides time for lap welding, and a single loop near the exit end of the line provides time for removal of the coil and the start of a new one on the single-drum coiler. The looping pits are each 50 ft deep and the strip hangs in a free loop, sensed and controlled photo-electrically.

The line has variable-voltage control for the entry flattener, the pinch rolls ahead of each entry loop storage, the drag bridle ahead of the furnace, the pulling bridle ahead of the exit and loop storage and the coiler. Catenary of the strip in the furnaces and pickle tanks is controlled by relationship between the pulling bridle speed and the drag bridle speed. The catenary is sensed by a rider roll and leverage which controls a rheostat.

Cold rolling—A sendzimir type reversing cold mill reduces the stainless strip to either intermediate or final gage.

The strip comes to the mill with a leader strip welded in place and wound on a 24-in. diameter solid drum. The mill can roll strip widths from 24 to 50 in. at speeds up to 715 fpm. Work rolls are 2.125-in. diameter and 55-in. face width.



This reversing cluster mill reduces stainless strip to either intermediate or final gage. It is located in the new No. 2 plant.

The mill is powered by a 1750-hp motor through a pinion stand. Each reel is powered by two 700-hp motors connected in parallel to a double input shaft reducer. Both the mill and the reels are controlled by separate variable-voltage control generator systems.

Motors and generators are housed in a motor room behind the mill. Incoming air is filtered by a tube-type air filter located on the roof. Down-draft ventilation of the motors is provided by suction fans located in the motor room basement. Air is exhausted through a duct to the outside of the building. Motor room temperature control is provided by dampers which recirculate a necessary portion of the air in cool weather.

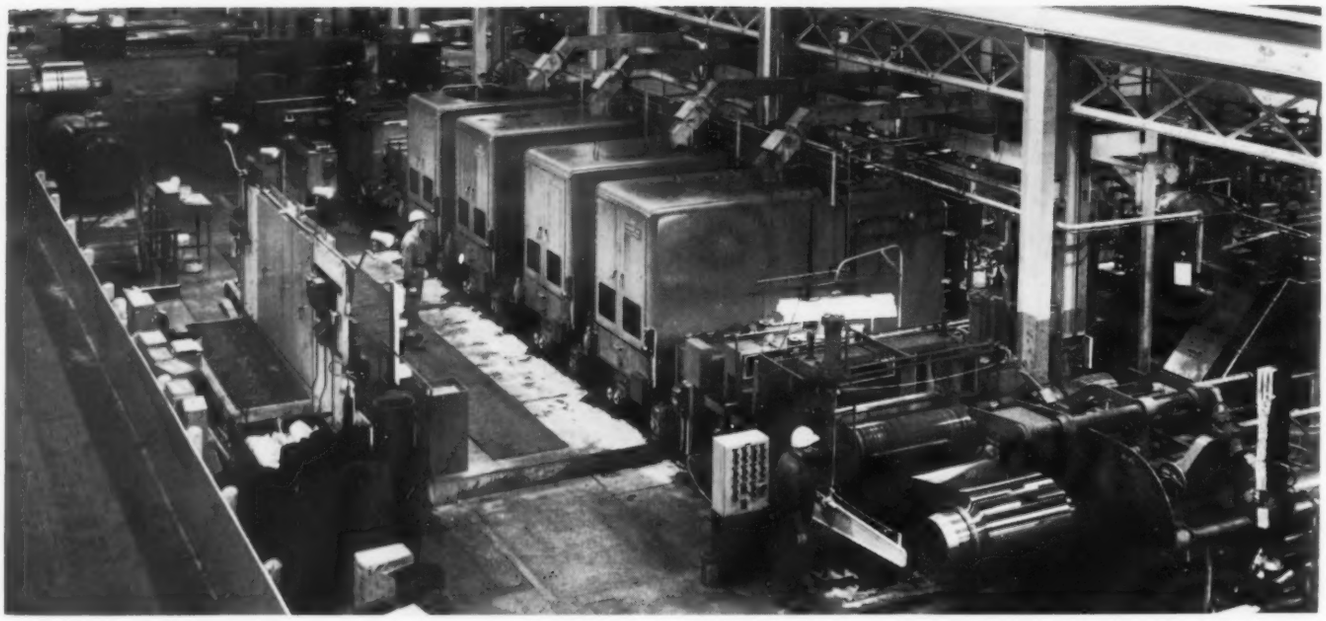
A centralized lubrication system located in a basement serves the pinion stand and the reel drives. It consists of a supply tank, filters, heat exchanger and pressure tank.

A separate coolant and lubrication system, located in the basement, serves the mill proper. The lubricant is pumped from a clean oil supply tank to the mill bearings and work roll sprays. The oil returns by gravity to a settling tank which overflows to a clean oil tank and is pumped again to the mill and sprays. Two other settling tanks are provided for periodic settling and reclaiming of the oil.

Other auxiliary equipment includes the hydraulic system, a fume or fog removal system and fog-type fire control for the oil cellar and the fume system.

A second mill is a 2-high nonreversing temper mill. It was built mainly from a 4-high mill moved from No. 1 plant. A new pinion stand and controls were provided. It can handle 51-in. maximum width and 0.100-in. maximum thickness at speeds up to 400 fpm.

The mill itself is powered by a 250-hp d-c motor controlled by a separate generator and variable-voltage system. The reels also operate in separate variable-voltage control systems from their own generators. The pay-off reel has a 75-hp motor used principally as a drag generator for supplying back tension. The ten-



Stainless strip may be gound in this belt grinder which has four grinding booths in tandem.

sion reel is powered by 150-hp motor which receives its control signal from a pilot generator on the mill drive motor.

Coil grinding—An important process in the finishing of flat rolled stainless is surface grinding. Depending upon the grade and the ultimate use, the strip may be ground with one or more passes on either one or both sides to remove imperfections which would otherwise be imbedded in subsequent rolling.

No. 2 plant has a 4-head, wet-method belt grinder which will handle all gages and widths processed in the plant. The unit is fed by an overhead crane which delivers coils that have been previously wound on a solid mandrel on the rewind line. Coils leave the unit on a solid mandrel, coiled with sufficient tension to be used directly on the sendzimir mill.

Line equipment consists of four grinding booths in close tandem, two oil spray booths (one at each end) wipers, pinch rolls and terminal equipment. One end is equipped to take the solid mandrels; the other end has a collapsible mandrel reel. This latter reel can either overwind or underwind so that both sides of the strip can be ground when desired.

An oil cellar beneath the unit contains the grinding oil or coolant tanks, filtering and sludge removal equipment. An inclined conveyor carries the grinding sludge to a tote box at floor level. A mist collector, a fog-type fire control system and a hydraulic unit supplement the line equipment.

Since the line is a reversing line, both reels have 75-hp d-c motors which also serve as drag generators for producing strip tension. The control uses a rate regulator, in place of the conventional motor-operated rheostat, with a single generator supply to control strip speed. Grinding heads each have a 125-hp a-c motor with V-belt drive.

Shear and temper rolling—A line is provided for shearing coiled strip into sheets, temper rolling the

TABLE V
No. 2 Plant—Slitters

	No. 9	No. 13	No. 16	No. 35 (new)
Type	Coil	Coil	Sheet	Coil
Speed, fpm	125 to 500, constant potential	125 to 500, constant potential	75 to 300, constant potential	125 to 500, adjustable voltage
Gage range, in.	0.062 to 0.156	0.010 to 0.062	0.010 to 0.156	0.015 to 0.125
Width, in.	48 maximum side trimmed width	48 maximum side trimmed width	39 maximum width	20 maximum side trimmed width
No. of cuts	Six on under 0.092 in. Four on 0.092 in. or over	Eight on under 0.050 in. Six on 0.050 in. and over	Eight maximum	Four on 0.093 to 0.125 in. Six on 0.063 to 0.092 in. Eight on 0.062 in. and under
Coil size, lb	20,000 maximum	20,000 maximum	...	15,000 maximum
Operation	Drive or pull through	Drive or pull through	Drive	Drive or pull through
Equipment in line	Pay-off reel and coil car Pinch roll Slitter Scrap chopper Coiler Overarm separator Stripper stand	Pay-off reel and coil car Slitter Tension drag Coiler Overarm separator Scrap baller	Entry roller conveyor Slitter Delivery belt conveyor Delivery table Scrap baller	Pay-off reel and coil car Pinch roll Slitter (two housing and arbor assemblies for quick change of setup) Tension drag Coiler Overarm separator Scrap baller Stripper stand

sheets, and roller leveling as necessary. Coils are delivered to the pay-off reel by tractor and fed through a pinch roll, flattener, shear, shear runout table, two tandem-sheet temper mills with runout tables, roller leveler and runout table. The mills are powered by a-c motors of 260 and 300 hp respectively. The line operates at constant speed throughout except for the feeding pinch roll and flattener.

Delivery speed can be set at a maximum of 225 fpm. Sheets are from 4 ft-0 in. to 20 ft-6 in. in length. They are removed on buggies and returned for a second temper pass or moved to the resquare shears. Sheet piling and paper interleaving is presently by hand.

Much of the equipment for this line, the temper mills, their entry tables, the shear and the leveler were moved from various locations in No. 1 plant altered or repowered as necessary and installed in No. 2 plant.

Slitting facilities—There are four slitting lines in the No. 2 plant. Three are relocated from the No. 1 plant and one line is new. The relocated lines handle side trimming and slitting of the wider widths. Slitting to narrower widths is done on the new unit. The slitter proper in the new line is equipped with two complete housing and arbor assemblies so that one can be setup or repaired while the other is in operation.

Table V summarizes pertinent data for these four slitters.

Other processing facilities—In addition to the foregoing, the plant contains:

1. An edger unit—This conditions either round or square edges and straightens slit strip as necessary in widths from two to eight in. in thicknesses 0.010 to 0.156 in. at speeds up to 150 fpm. Coils are sheared to ordered length on this unit.
2. Resquare shears.
3. Circle-cutting shears.
4. Stretcher leveler (hydraulic).
5. Roller leveler.

Utilities and services—Power for the No. 2 plant is purchased at 25,000 volts, 60-cycle from the local power company and supplied to a 10,000-kva, 25,000/7200-volt transformer and switching substation which in turn feeds various switchgear and load centers throughout the plant.

Process steam at 150 psi is supplied by two 15,000-lb per hr package boilers. The boilers and auxiliary pumps and controls, as well as two air compressors, are located in a 40 x 60-ft boilerhouse outside the south end of the plant.

Two air compressors, one as standby, supply 600 cfm of compressed air at 100 psi.

Water supply from the small stream adjacent to the plant is not adequate for the plant, so a carefully planned water reclaiming and recirculating system is employed. Two principal systems are operated: a cooling tower system and an acid neutralizing system. A 2-cell, 4000-gpm cooling tower supplies cooling water to the cold mills and the anneal and pickle line.

A neutralizing plant handles the pickling rinse waters and waste acids from the anneal and pickle line. The waste is collected in a lined tank at the processing line and pumped to the neutralizing plant mix tanks at a controlled rate. There, the wastes are chemically treated and coagulated. The treated water flows to a clarifier for settling-out of solids. The clarified water flows by gravity to storage from where it is pumped back to the pickling rinse. Also, a portion is used in the chemical feeders. Solids which settle in the clarifier are mechanically raked to an outlet and flow to a vacuum filter for dewatering. The sludge cake is removed by conveyor and hauled to a dump. The system capacity is presently 200 gpm of acid rinse water. Space has been allowed and some portions of the system sized to allow for future additions.

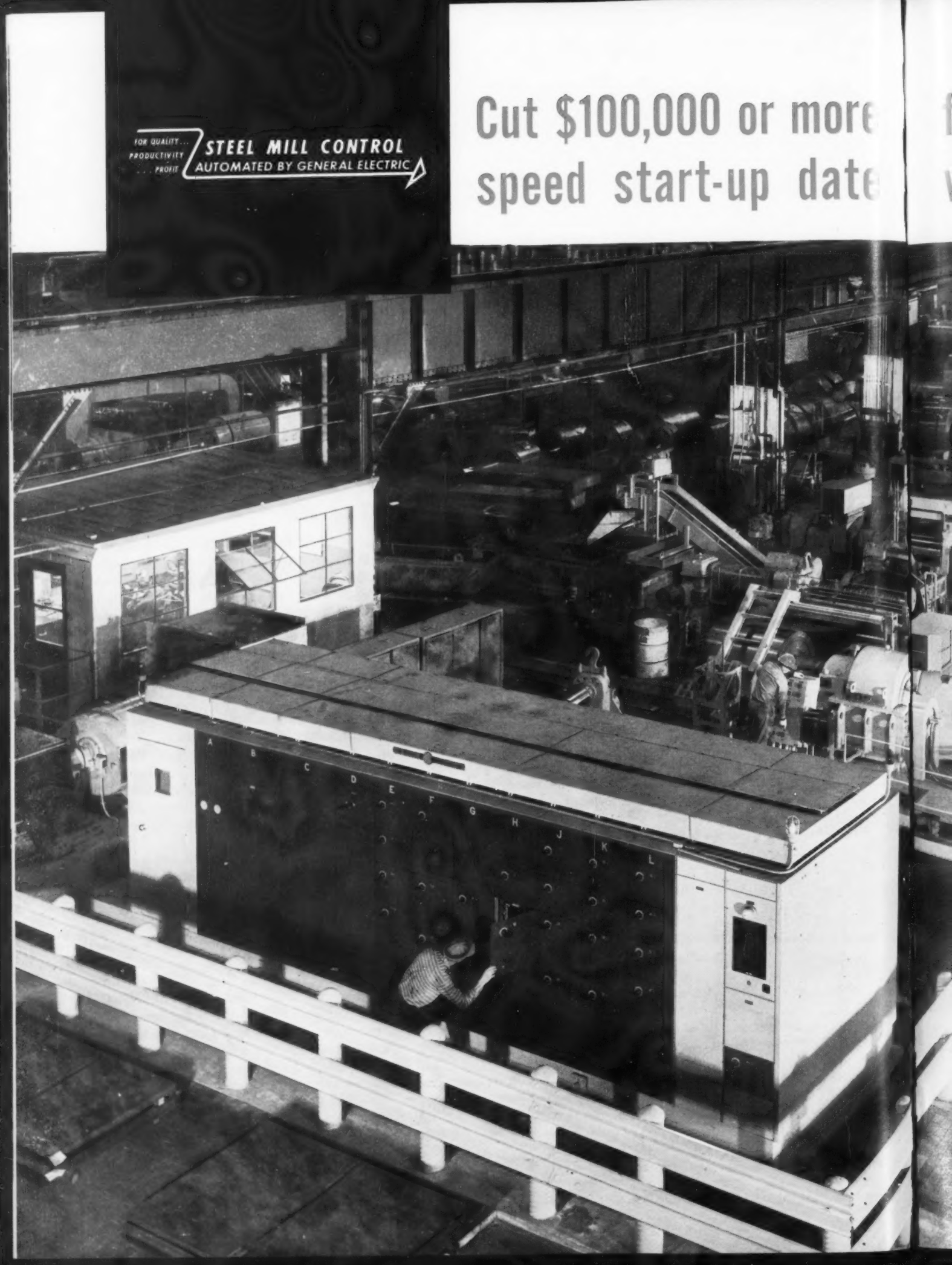
Great care is taken to avoid damage in shipping flat rolled products.

Some portions of No. 2 plant processing or auxiliary equipment require noncontaminated water. This, as well as drinking water and sanitary service water, is purchased from the city water system. An elevated water storage tank of 125,000-gal capacity was erected at the south end of the property to ensure a constant supply and to act as emergency standby for cooling and processing supply.

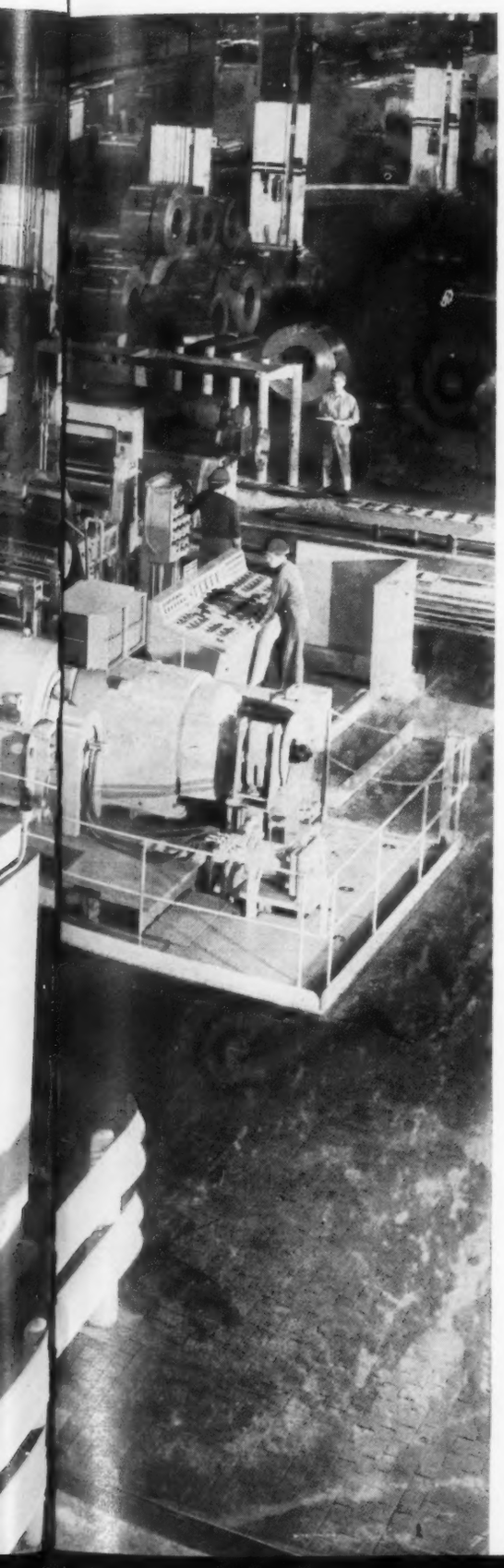
Concentrated acids for pickling are received by either rail or truck and are pumped to elevated 18,000-gal storage tanks. From here, the acids flow by gravity in lined pipes to the acid metering equipment at the pickling line.

Material is handled in No. 2 plant by overhead bridge cranes serving the cold mills, coil grinder, rewind line, shearing and shipping areas. This is supplemented by ram-type lift trucks and push-pull tractor. The anneal and pickle line has only 3-ton travelling maintenance cranes overhead. Coil handling is by lift truck. The acid neutralizing plant uses a lift truck for unloading and handling bagged lime on pallets. For general service and maintenance of overhead lights and equipment, a mobile insulated hydraulic lift platform is used.

A roll grinder shop located in an area adjacent the sendzimir mill presently contains a 14 x 72-in. cylindrical grinder and related equipment for the conditioning and storage of mill rolls. ▲


FOR QUALITY... PRODUCTIVITY ... PROFIT
STEEL MILL CONTROL
AUTOMATED BY GENERAL ELECTRIC
Cut $100,000 or more
speed start-up date

from installed cost of mill power supply, with General Electric power-control room



It's a fact! A General Electric power-control room can save you $100,000 or more in total installed cost of mill power supply, and will cut weeks from the start-up time.

This modern, custom-built unit—for control of rolling and processing lines—groups all power-supply equipment into a compact, pre-engineered, self-supporting structure, which is completely factory wired and tested. Power conversion, control, ventilation, and other equipments are not scattered around the mill . . . eliminating the need for expensive cable systems. Actually, $100,000 is a conservative estimate of savings. In some cases, savings in cable alone total that much. Other big savings can come from elimination of separate motor room (up to $12,000), separate ventilation system (as high as $20,000), special foundations (up to $7,000), and major check-out and tune-up (can cost more than $5,000).

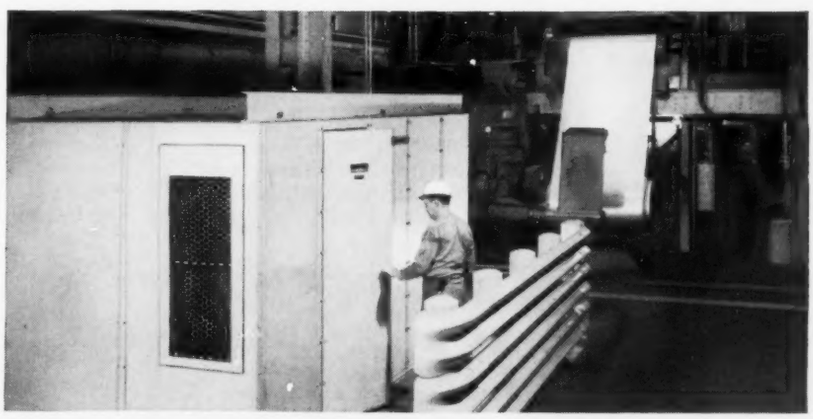
Preparation for start-up, which takes weeks with conventional equipment, can be completed in days with a G-E power-control room. Because General Electric supplies engineering drawings immediately after design is finished, you can make many necessary preparations in advance of delivery. With all inter-control wiring and system testing completed before shipment, you need make only final connections and tune-up prior to operation. Faster start-up means your mill investment is producing salable output sooner.

Seventy-five years of experience in developing and building control equipment and systems for the steel industry stand behind General Electric's power-control room. Include a G-E power-control room in your modernization plans. And, call on General Electric for all process control. See your G-E sales representative, or write Section 785-17, General Electric Co., Schenectady 5, N. Y.

Industry Control Department, Salem, Virginia.

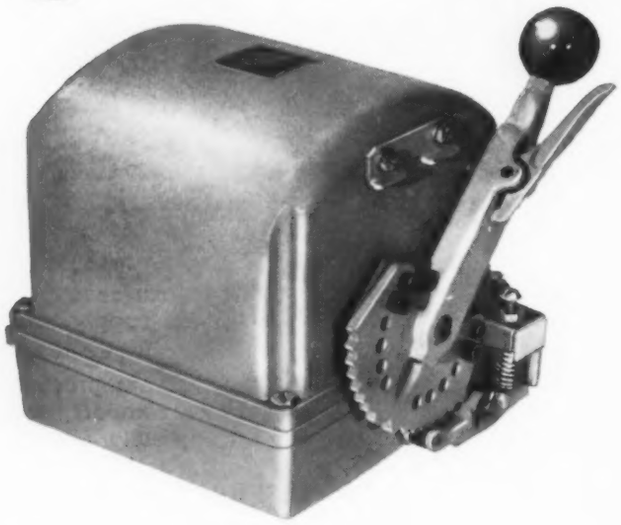
Progress Is Our Most Important Product

GENERAL ELECTRIC



A POWER-CONTROL ROOM, such as the above at Armco Steel's Butler, Pa. Works, can reduce space requirements up to 50 percent. Put it in the best location—right beside the mill or in previously unusable space.

MILL-DUTY ACCESSORIES



MASTER SWITCHES

Heavy-duty design offers long life, high reliability

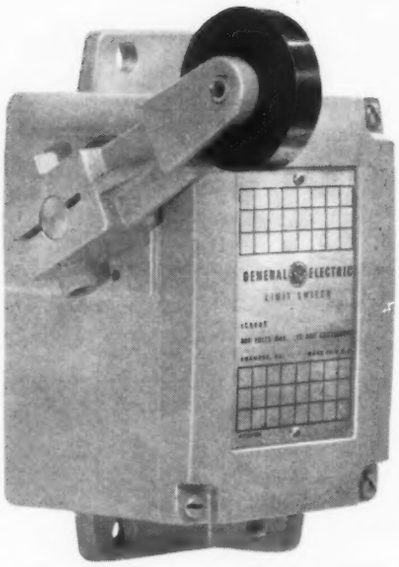
Self-lubricating phenolic cams—impregnated with graphite—keep General Electric master switches performing longer . . . even in the toughest conditions. Numerous mill installations show that these cams—coupled with steel cam followers—will operate millions of times without replacement.

Modern design of the G-E master switch permits quick modification—with a minimum of parts—to perform different sequences. And, cams can be interchanged without disassembling the switch. Offered in surface- or desk-mounted models, these switches are 25% smaller than other designs.

Check these "extra-value" features of General Electric master switches:

- **Entire switch unit** lifts out of enclosure for ease of wiring and mounting.
- **Pawl arrangement** allows for convenient adjustment to each operator's "feel."
- **Adjustable stops** give maximum of seven points in each direction, plus off.

Want more information? See your G-E Sales Engineer; or write Sect. 784-28, General Electric Co., Schenectady, N. Y. for Bulletin GEA-6706. *Industry Control Dept., Salem, Va.*



LEVER LIMIT SWITCHES

New adjustable cams permit fast, on-the-job adaptation

Here is a new lever-operated limit switch that lets you adapt it to the application . . . right on the job. You no longer need to predetermine circuit requirements before selecting a device. This means fast installation or quick adaptation when requirements change. A new system of adjustable cams on General Electric's lever limit switch makes this flexibility possible. A template—provided with every switch—guides changing the cams.

Lighter and more compact, General Electric limit switches are available for either two- or four-circuit operation . . . and, in a wide choice of enclosures.

Consider these key features of the new General Electric lever limit switch:

- **Readily-accessible contact blocks** are of unit construction, easy to wire.
- **Variety of levers** offers wide selection to meet your specific application.
- **Starwheel** may be set for either maintained or spring-return operation.

For the complete story, see your General Electric Apparatus Sales Engineer, or write Section 784-28, Schenectady, N. Y. for Bulletin GEA-7203. *Industry Control Dept., Salem, Virginia.*

Progress Is Our Most Important Product

GENERAL ELECTRIC

Representative packages of Armco steel ready for shipment

Signode is proud to be serving Armco Steel

The strength of steel strapping, used with interested skill and ingenuity, helps make Armco steel cost less per ton. Signode packaging specialists work with Armco men on a continuing basis. They help to develop strapping methods and to select dependable Signode tools and machines that improve product protection while they reduce packaging material costs and packaging time.

First in steel strapping

SIGNODE
STEEL STRAPPING CO.
2644 N. Western Avenue • Chicago 47, Illinois
Offices Coast to Coast, Foreign Subsidiaries and Distributors World-Wide
In Canada: Canadian Steel Strapping Co., Ltd., Montreal • Toronto

Armco picks a winner!

MURRAY-WAY'S MICRO-POLISH EQUIPMENT FOR WET GRINDING STRIP STEEL

Murray-Way is the leading specialist in the metal polishing field. Murray-Way equipment grinds more steel, in more steel mills, all over the world, than any other make.—CONSIDER THESE POINTS OF LEADERSHIP!

1ST to develop practical, efficient equipment for wet grinding of stainless coil stock. The first, installed in 1951, still in daily use.

1ST to develop practical, efficient equipment for wet grinding of flat carbon steel. In daily use by automotive and appliance manufacturers since 1948.

1ST to incorporate a heavier frame, massive main brackets and huskier bearings necessary for dependable, high-precision finishing in large volume production.

1ST to provide adequate sludge removal facilities inside the frame. A tremendous saving in down-time and maintenance effort.

1ST to perfect "gage differential" grinding of continuous steel strip—with coil under full tension. Provides over-all surfacing of strip which varies in gage dimension from edge to edge.

1ST with really close-tolerance production grinding, (± .0005), for the aircraft industry. Murray-Way's specially engineered billy roll and frame construction, plus a unique, simple method of contact roll dressing, makes this equipment ideally suited for close tolerance work.

1ST with exclusive, trouble-free, "air eye", belt oscillation control. No levers, pads or electrical equipment. It practically eliminates belt control problems and maintenance.

1ST with "free-floating" belt tensioning and billy roll construction. Permits axle expansion under production loading without going "out of true", breaking, or causing bearing destruction.

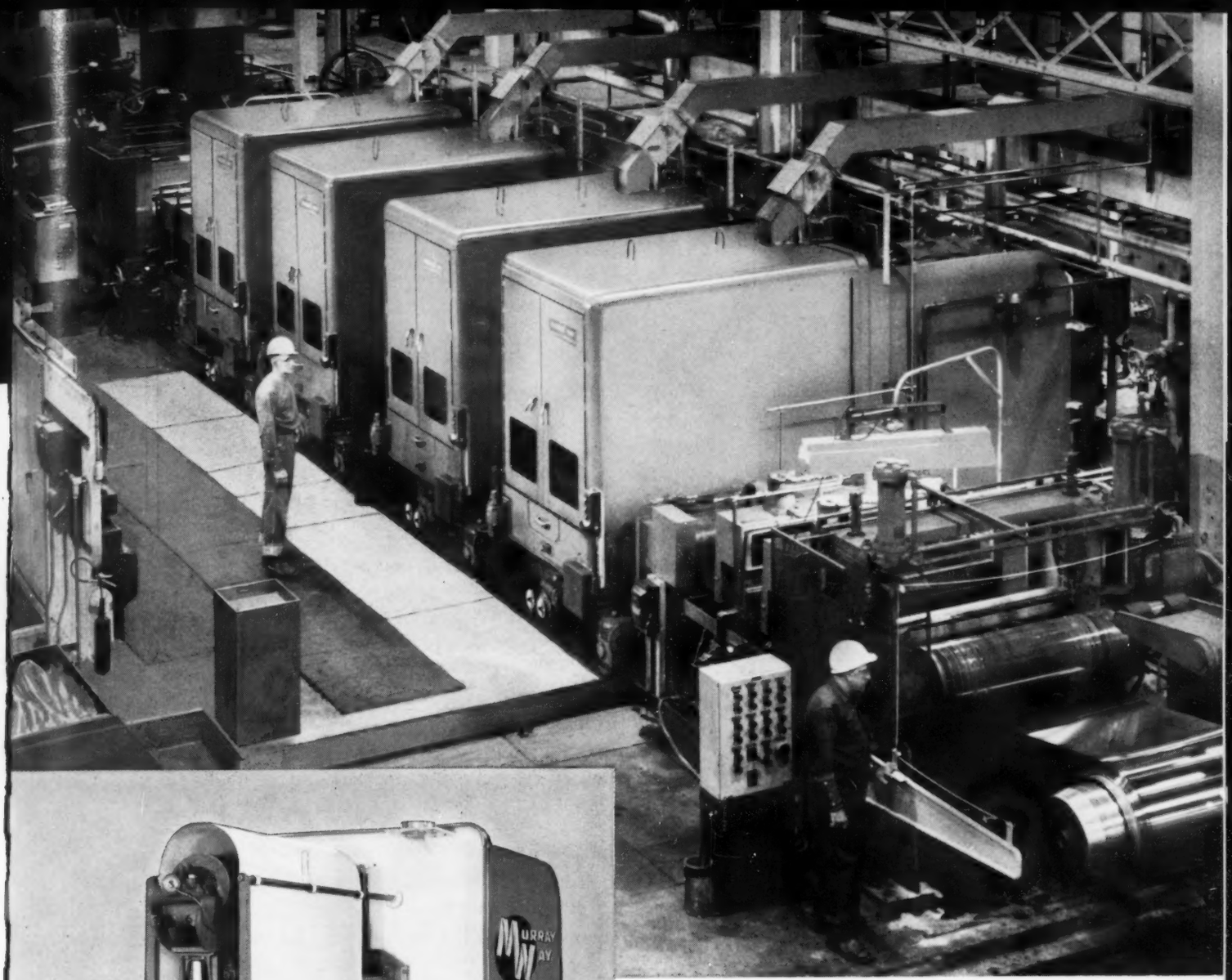
and now announcing!

1ST a coolant spreader that cleans itself without machine stoppage. Easily adjustable to various belt widths in a few seconds.

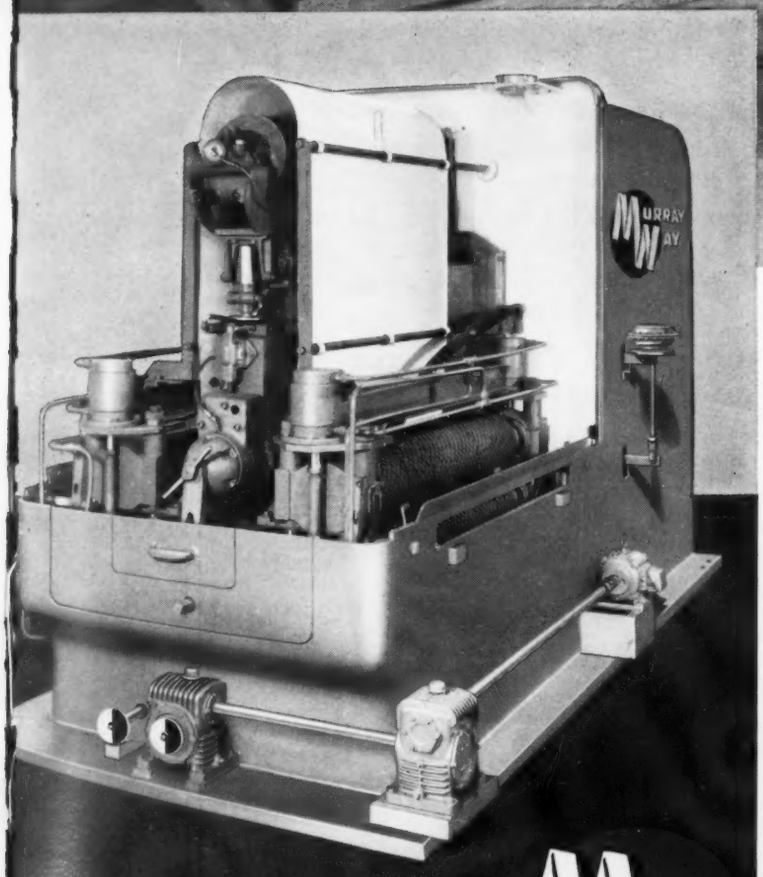
1ST an automatic, work pressure control system. Achieves uniform, top grinding efficiency for entire belt life.

COMING— Comprehensive test data pinpointing proper abrasive belt use. Available to all Murray-Way users. AND several new FIRSTS not yet ready for release.

When you buy MURRAY-WAY, you are buyin



Armco's newest Micro-Polish strip grinding installation . . . their third purchase of this Murray-Way quality control equipment.



View of a Micro-Polish unit with hood removed. Note the simple, sturdy construction.

MURRAY-WAY is headquarters for better mechanical metal finishing equipment.

MURRAY-WAY'S experienced engineers HAVE the answer to your metal grinding, polishing and buffing questions. Your project *will not* be an experiment.

MURRAY-WAY'S outstanding engineering achievements in this field are well known throughout the world.

MURRAY-WAY not only is "first-with-the-best", but maintains its superiority through an alert, continuing research and development program.

MURRAY-WAY'S dependability is the result of years of experience plus quality construction — a combination that means BETTER RESULTS AT LOWER COST for you.

MURRAY-WAY CORPORATION

P.O. BOX 180 • MAPLE RD. EAST BIRMINGHAM, MICH.

the best!

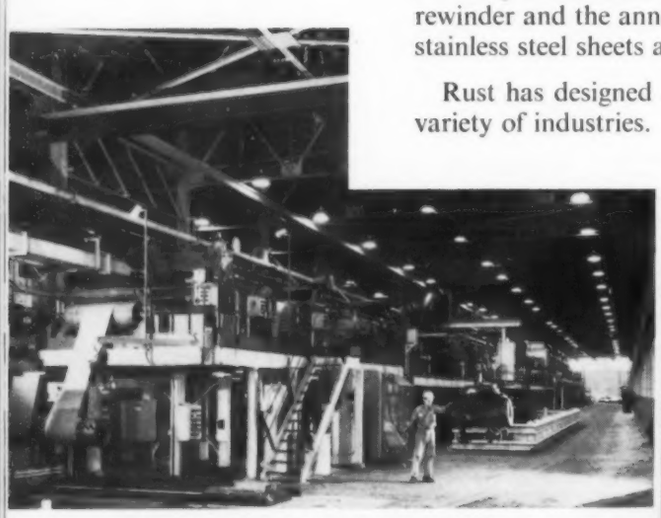
PRODUCTIVE LANDMARK
for Economic Growth

Armco's New Stainless Plant at Butler Works
constructed by RUST

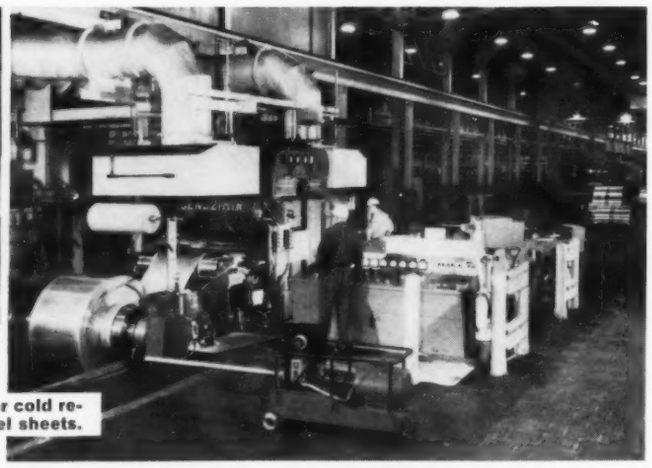
This plant is now processing quality Armco stainless steel with modern equipment in an enlarged and modernized building. The stainless plant is a new "Productive Landmark" in the community.

The Rust Engineering Company constructed the plant extension and its auxiliary facilities and erected the 53″ cold reduction mill, coil grinder, coil rewinder and the annealing and pickling line for the production of 48″ wide stainless steel sheets and coils.

Rust has designed and constructed many "Productive Landmarks" for a variety of industries.



Annealing and pickling line erected by Rust.

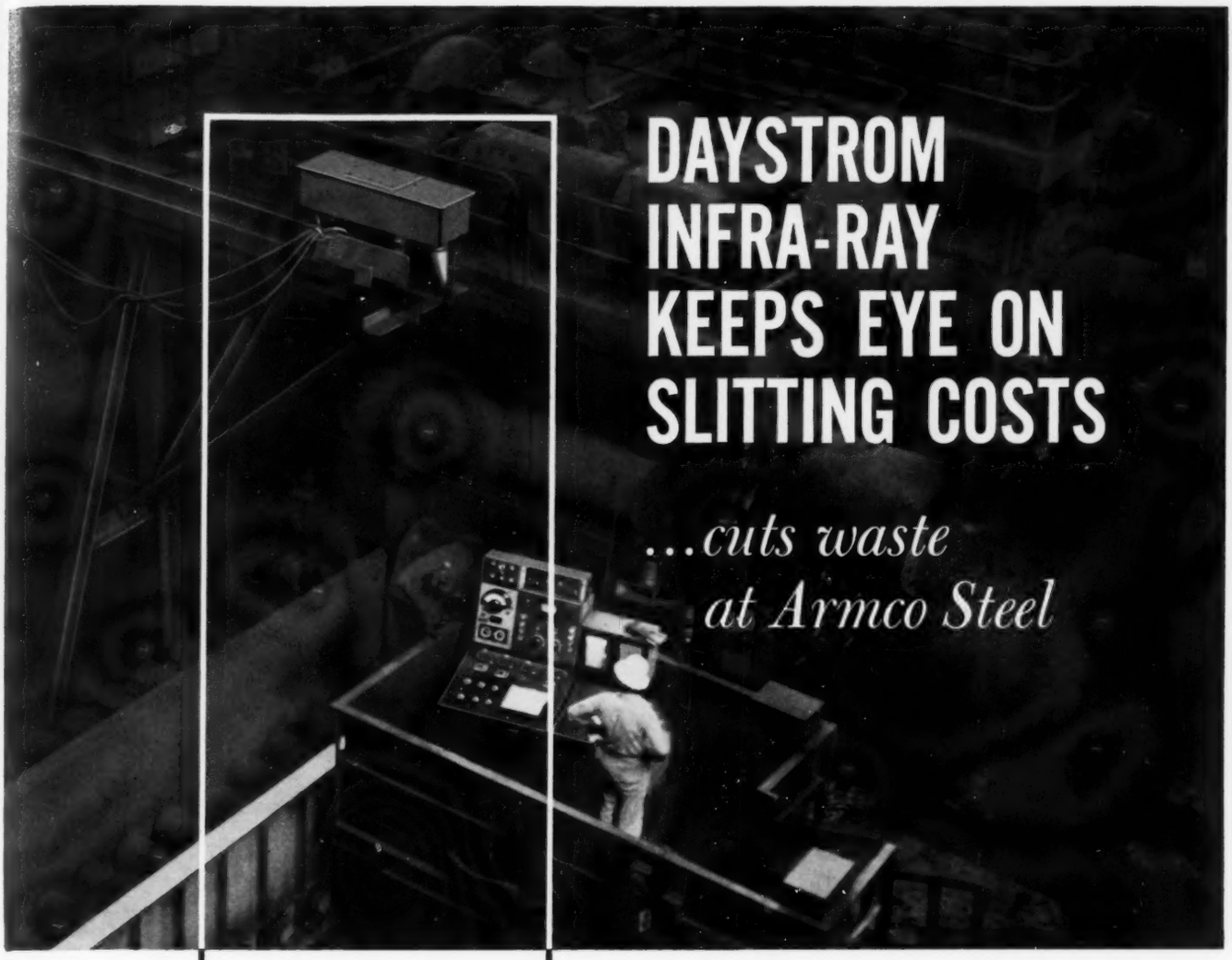


53″ Sendzimir mill for cold reducing stainless steel sheets.

THE RUST ENGINEERING COMPANY

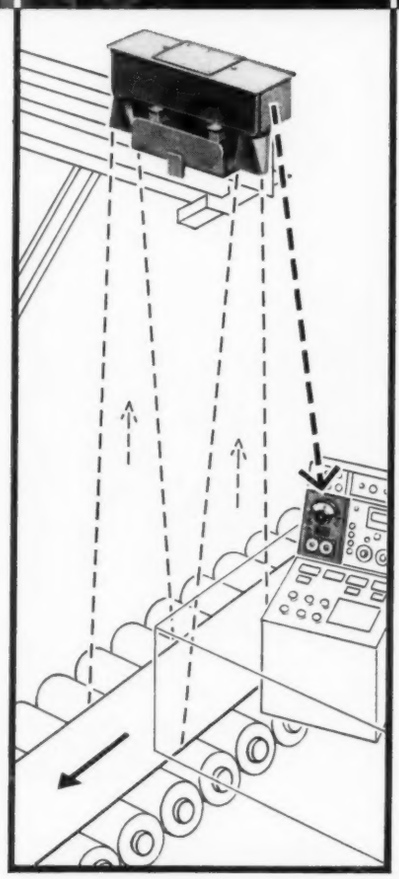
930 Fort Duquesne Boulevard, Pittsburgh 22, Pa.
2316 Fourth Avenue, North, Birmingham 3, Ala.

RE-3



DAYSTROM INFRA-RAY KEEPS EYE ON SLITTING COSTS

...cuts waste at Armco Steel



Armco effectively increased yield in strip steel production by using the Daystrom Infra-Ray for precise width control. Since installing Infra-Ray at its Butler, Pa. mill, Armco reports considerable savings on scrap.

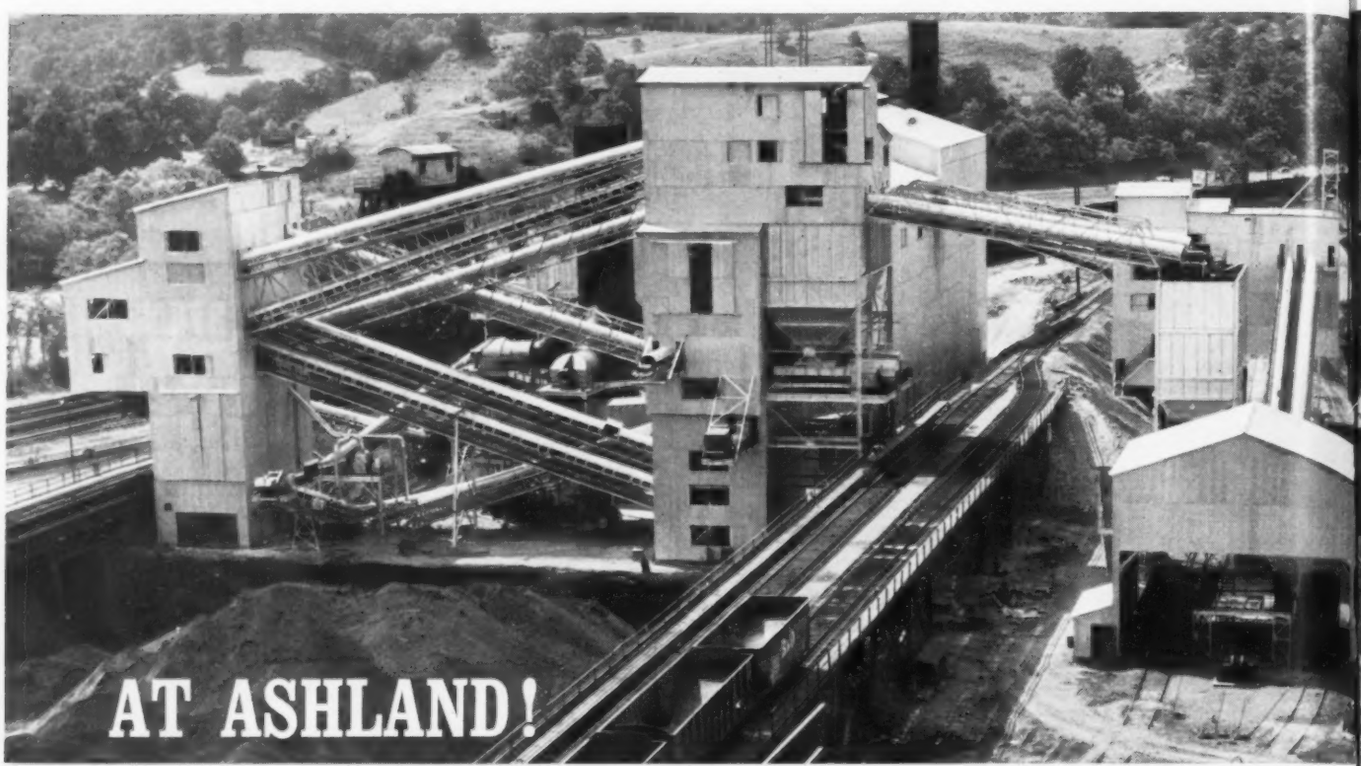
An infrared sensing head—mounted high above the hot steel—actually "sees" minute width changes in the fast-moving strip as it emerges from the finishing stands. Quality control is simplified since speed operators can easily read width variations and change the rolling rate.

Daystrom's Infra-Ray has a guaranteed accuracy of ±⅛" at strip speeds up to 2,000 feet per minute. It operates with an edge heat of 900F or more, is unaffected by rolling speed changes, steam and oxide dust. Periodic calibration for various strip sizes is simple and accurate.

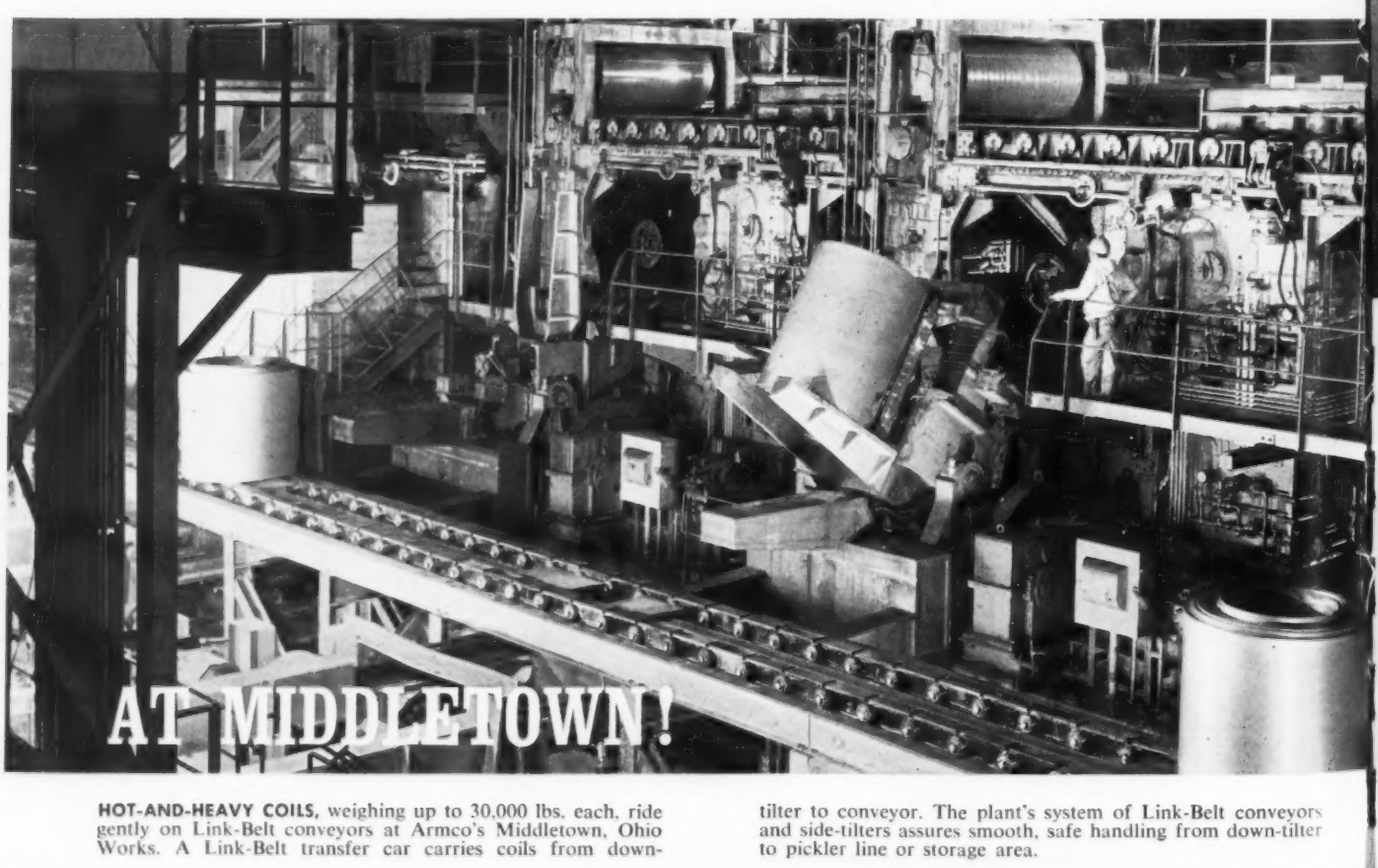
Daystrom technical representatives will gladly show you how to cut *your* costs with Infra-Ray. For information, contact: Daystrom, Incorporated, Weston Instruments Division, Poughkeepsie, N. Y. *International Sales Division: 100 Empire Street, Newark 12, N. J. In Canada: Daystrom Ltd., 1480 Dundas Highway East, Cooksville, Ontario.*

DAYSTROM, INCORPORATED
WESTON INSTRUMENTS DIVISION
Reliability by Design

Link-Belt conveyors at ARMCO PLANTS

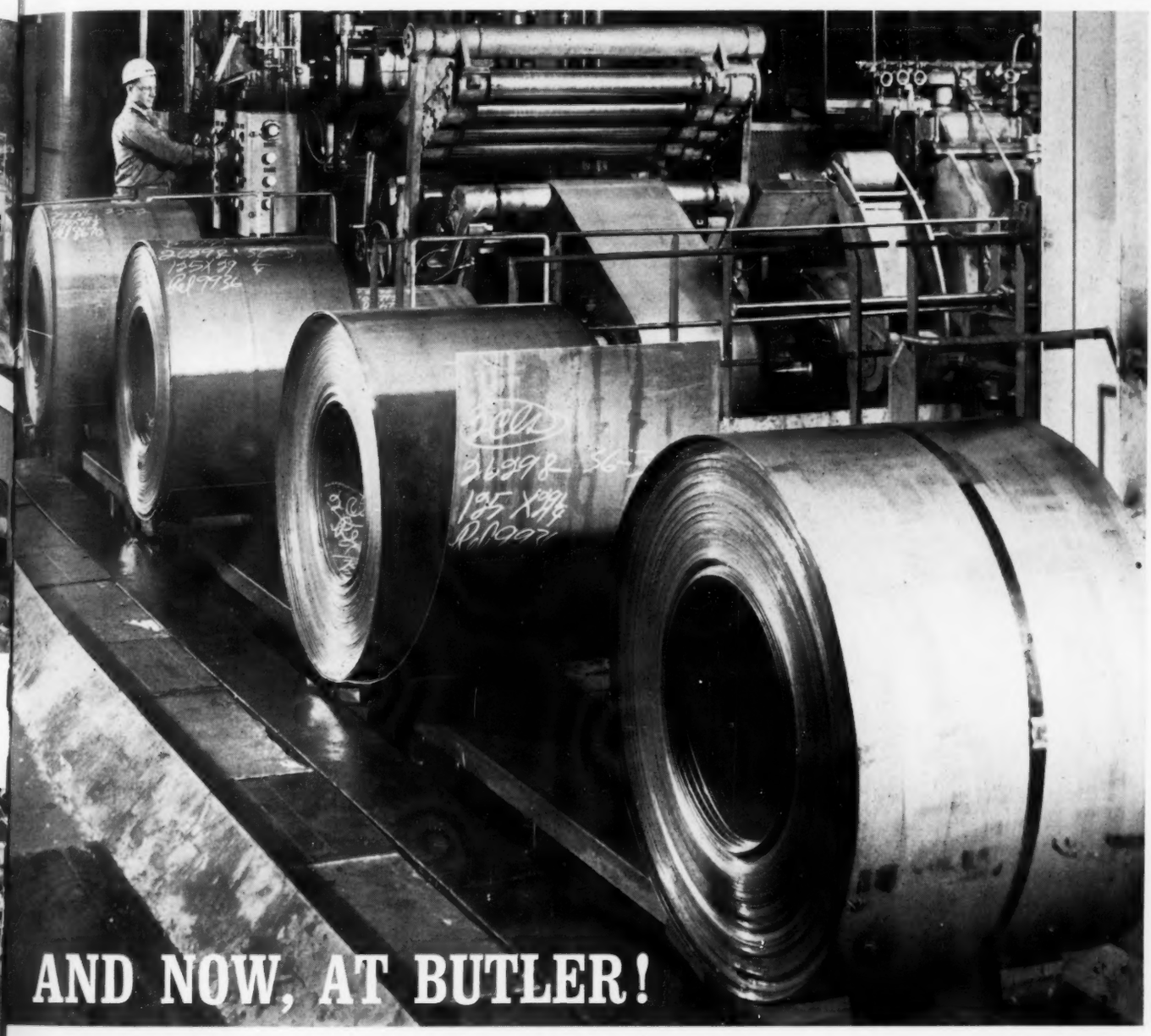


COMPLETELY CONVEYORIZED SINTERING PLANT! All raw materials and sintered ore travel on Link-Belt conveyors at Armco's 2400-ton-per-day sinter plant in Ashland, Ky. The intricate Link-Belt conveyor network provides unusual handling flexibility . . . makes it possible to carry out complex conveying procedures, despite the plant's space limitations.



HOT-AND-HEAVY COILS, weighing up to 30,000 lbs. each, ride gently on Link-Belt conveyors at Armco's Middletown, Ohio Works. A Link-Belt transfer car carries coils from down-tilter to conveyor. The plant's system of Link-Belt conveyors and side-tilters assures smooth, safe handling from down-tilter to pickler line or storage area.

keep materials and coils on the move



LINK-BELT SADDLE-TOP CONVEYORS keep a steady stream of coils moving to and from a 5-stand cold reduction mill at Armco's Butler, Pennsylvania Works. Traveling at 25 fpm, the conveyors carry coils smoothly, safely . . . no telescoping, no edge damage. In another part of the plant, a Link-Belt continuous-top-plate conveyor transfers coils between buildings.

The new Butler, Pennsylvania Works is the third Armco Steel Corporation plant being served by Link-Belt. In all three, Link-Belt conveyors contribute to the swift, sure, coordinated handling so essential for profitable steel production.

And in many other modern mills throughout the steel industry, Link-Belt conveyors are providing similar handling efficiency . . . helping to boost production, cut waste, improve safety, reduce physical effort. Some solve problems of storing and reclaiming ores, coke, stone, pellets and sinter. Others transport high-tonnages of steel in every form . . . quickly, yet gently enough to minimize scrap losses.

Whether you're planning a new plant or modernizing, Link-Belt engineers will gladly work with your own engineers and consultants to help you achieve profitable handling. For full details, contact your nearest Link-Belt office. And also ask to see our 16 mm. sound-color film, HANDLING MATERIALS IN THE STEEL INDUSTRY.

LINK-BELT

MATERIALS HANDLING, PROCESSING AND POWER TRANSMISSION MACHINERY

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses and District Sales Offices in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World. 15,724

No more hand stacking. This newspaper counter-stacker counts and stacks newspapers automatically—and can be programmed to automatically vary the stacks to meet route schedules.

No more dry pumping. Cutler-Hammer's new development—an automatic pump off control for stripper oil wells—stops the pump when oil has been lifted. Saves the pump, ups production.

CONTROL

What's new in control for automation?

A blast furnace that charges itself

More efficient automation because the Cutler-Hammer control systems man was called in at the start of planning. The art of charging a blast furnace is now a science.

Cutler-Hammer control engineers, with the furnace builders, worked three years to put all charging control functions into one integrated system. Now, the proper material in the proper amounts, all in a proper sequence are delivered to the furnace bell—automatically.

Every step of the operation can be checked visually on master control panels. Nothing is left to chance. The added cost of this kind of charging control is relatively insignificant. Complete flexibility in selection of furnace charging programs now makes possible optimum blast furnace performance.

Why you should call in the electrical control man early. Cutler-Hammer has been increasing productivity and lowering costs for many different companies in many different industries for years. This is a major reason why Cutler-Hammer should be called when you *start your automation planning.*

The company on the move. There's a new vitality at Cutler-Hammer—a new desire to solve problems. We've planned for the gigantic expected growth of the sixties and now we're ready—with new plants, new engineering talent, new and better products. We'd like to tell you about ourselves if you're planning ahead. Contact the Cutler-Hammer sales office nearest you.

Automation is more efficient when the control expert is called in early.

WHAT'S NEW? ASK...

CUTLER-HAMMER

CONTROL

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.

New **UNITED**®

56" 4-HIGH, 4-STAND TANDEM

COLD MILL

AT ARMCO STEEL CORPORATION, BUTLER WORKS

PLANTS AT: Pittsburgh, Vandergrift, Youngstown, Canton, Wilmington. SUBSIDIARIES: Adamson United Company, Akron, Ohio: Stedman Foundry and Machine Company, Inc., Aurora, Indiana.

Designers and Builders of Ferrous and Nonferrous Rolling Mills, Mill Rolls, Auxiliary Mill and Processing Equipment, Presses and other heavy machinery. Manufacturers of Iron, Ductile Iron and Steel Castings and Weldments.

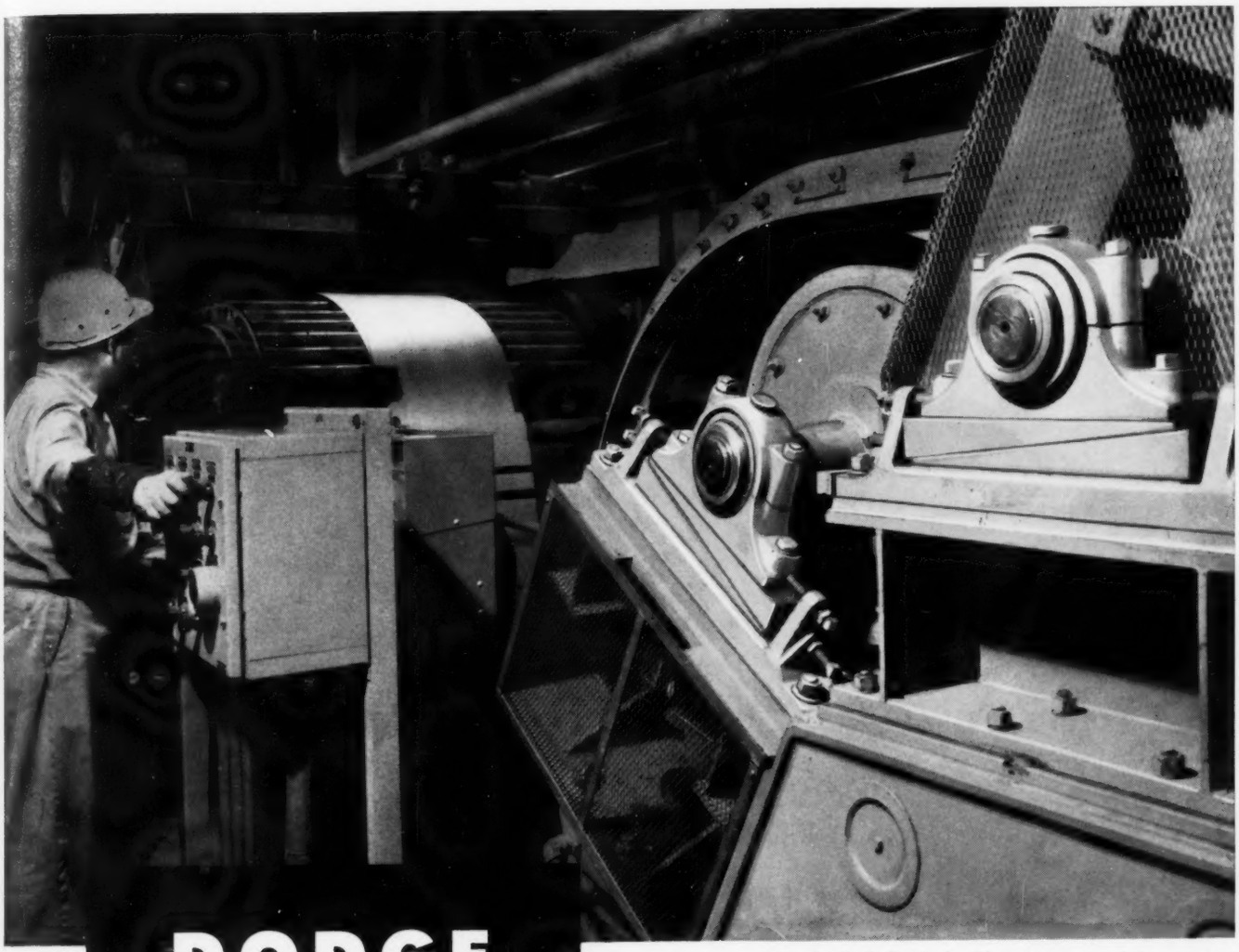
UNITED

ENGINEERING AND FOUNDRY COMPANY

PITTSBURGH 22, PENNSYLVANIA

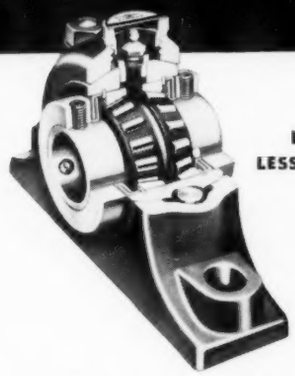
1901 UE&FCO 1961

Progress...Leadership
United for Sixty Years



Drag Bridle Rolls, Butler Plant, Armco Steel Corporation

DODGE
PILLOW BLOCKS WITH TIMKEN BEARINGS



LONGER LIFE
LESS MAINTENANCE

The entire annealing and pickling line at the new addition to the Butler plant of Armco Steel Corporation is equipped with Dodge Double Interlock Pillow Blocks. These are subjected to acid fumes, heat and moisture. Double Interlocks take all this in stride. Double labyrinth grease and dust seals protect the precision Timken tapered roller bearings against contamination. The pillow blocks are fully self-aligning. And they take *any* combination of radial and thrust loads.

There are 5 types of Dodge Pillow Blocks with Timken Bearings—for practically any service condition. They are stocked by your Dodge Distributor—assembled, adjusted, lubricated and *sealed* at the factory—ready for the shaft. Ask your distributor, or write us for complete technical bulletin.

Dodge Manufacturing Corporation
5900 Union Street, Mishawaka, Indiana

The Products with the Pluses... **DODGE** *of Mishawaka, Ind.*

CALL THE TRANSMISSIONEER, your local Dodge Distributor. Look under "Dodge Transmissioneer" in the *white* pages of your telephone book. Factory trained by Dodge, he can give you valuable assistance.

"Reducing your cost of p

ARMCO STEEL, using TSP hardened products since 1911, has saved thousands of dollars in maintenance, replacement and down-time costs. Our products can deliver these gratifying results because of our unique and exclusive heat treating and hardening techniques.

Our Company's continuing devotion to basic metallurgical research has paid handsome dividends to our many customers in all major U. S. industries.

We are very grateful to our many customers who constantly encourage us with successful reports on TSP hardened products.

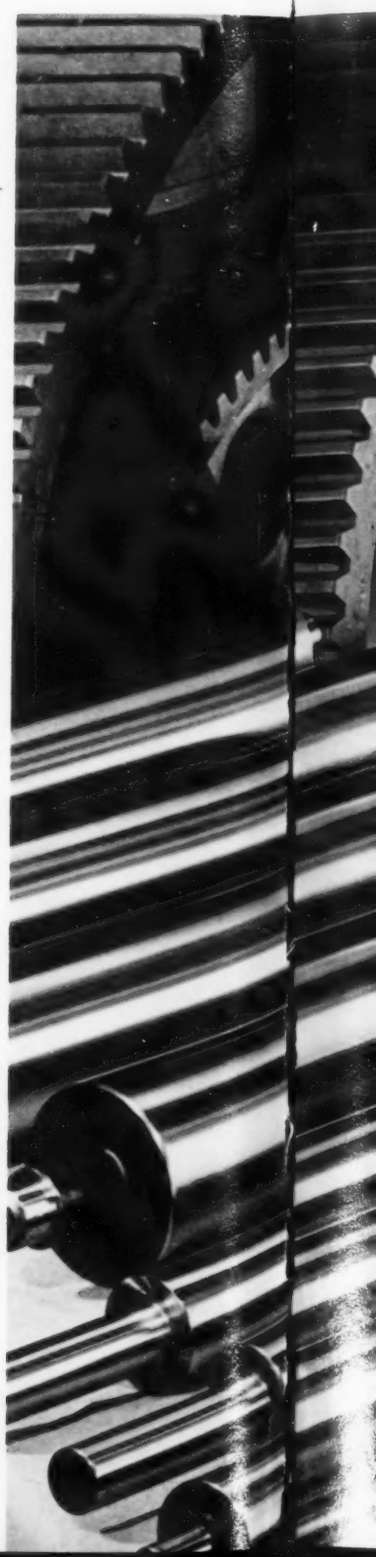
Many TSP products including rolls, pinions, gearing, crane wheels, screwdown screws and nuts, drum sleeves, etc., are used at ARMCO.

THE TOOL STEEL GEAR & PINION COMPANY

CINCINNATI / OHIO / USA

THE STANDARD OF QUALITY SINCE 1909 FOR GEARS, PINIONS, ROLLS, WHEELS AND OTHER HARDENED PRODUCTS.

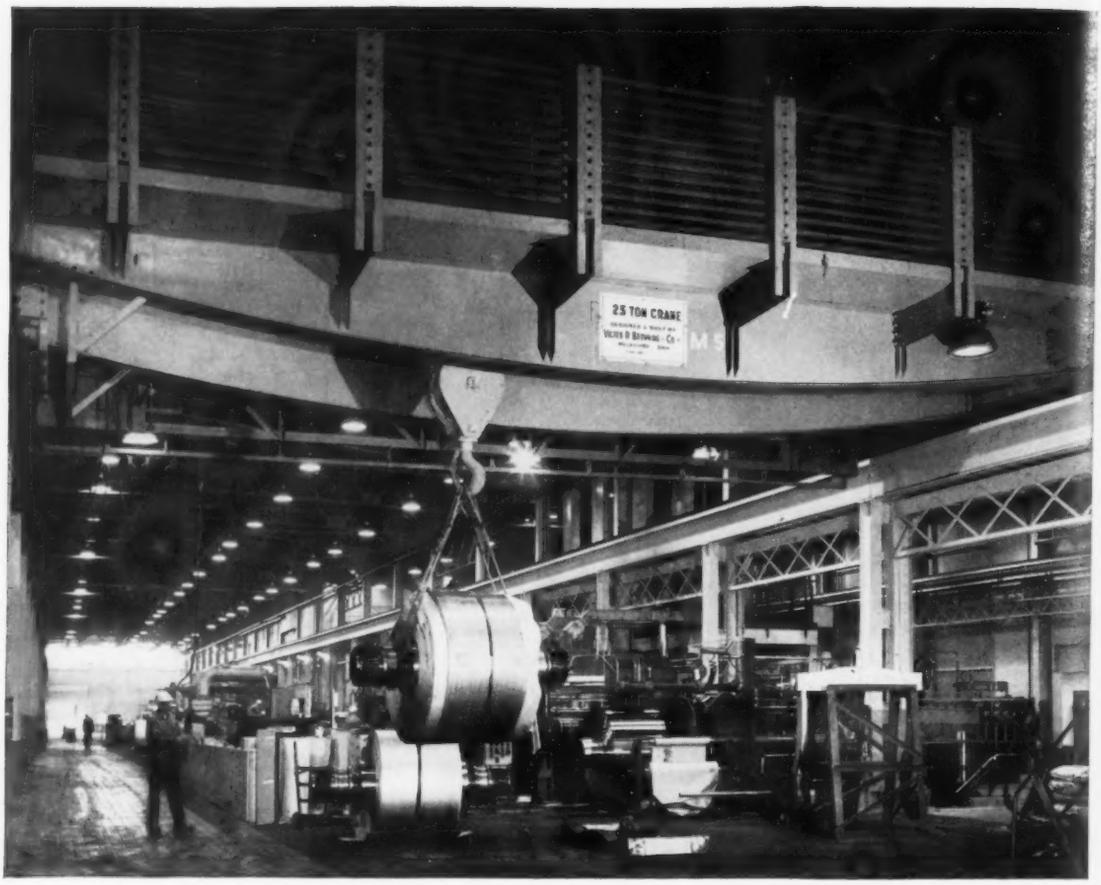
MEMBER OF AGMA



AD 1057 Printed in U.S.A.

f production is our business"

Leroy Brooks, Jr., Chairman of the Board, The Tool Steel Gear & Pinion Co.



ARMCO USES

Browning Cranes

Here you see one of a number of Browning heavy duty mill cranes in operation at the Butler, Pa. works of The Armco Steel Corporation.

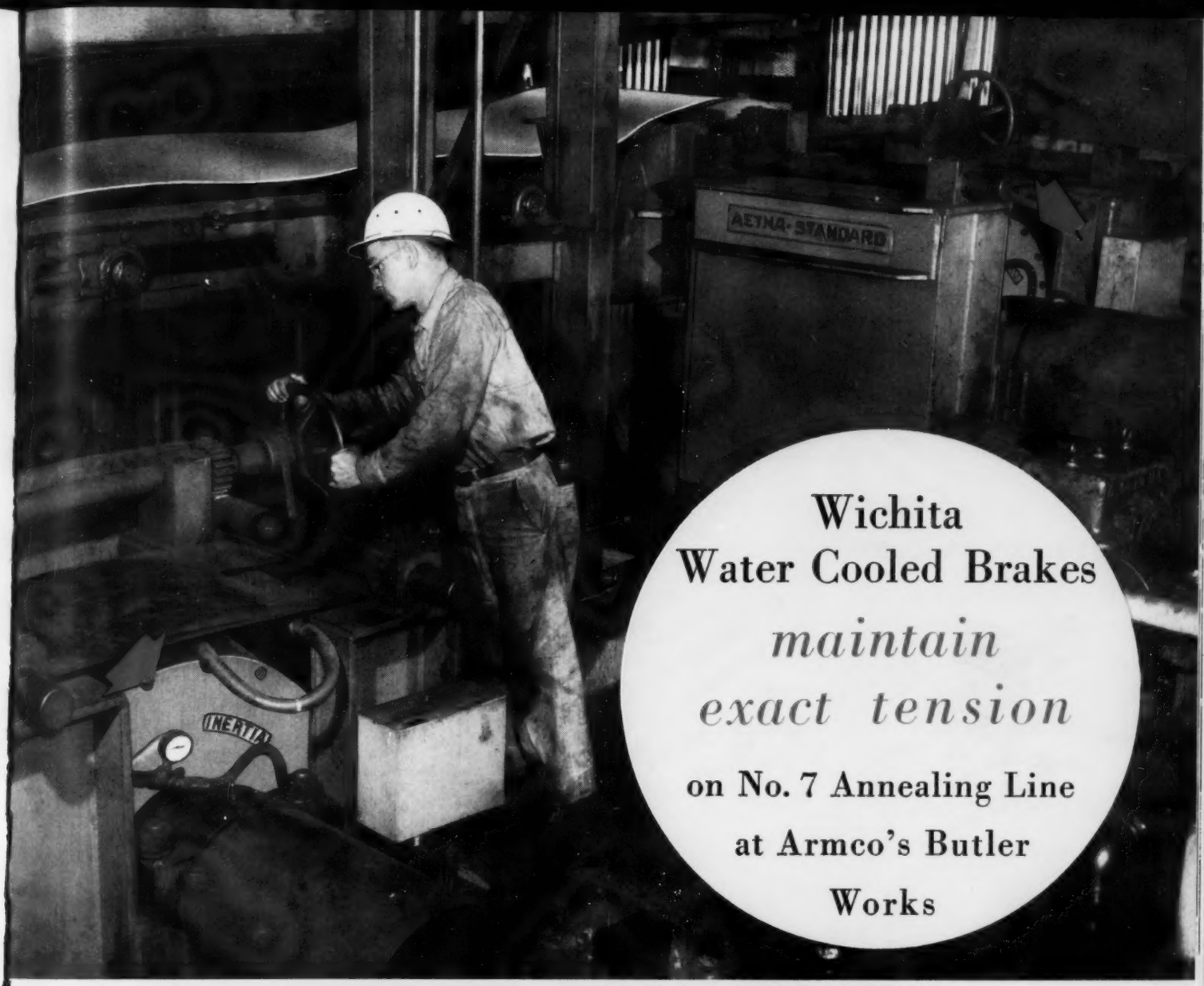
Browning mill type cranes are built to stand the severe service encountered in steel mills and heavy industry. They meet or exceed A. I. S. E. Specifications. We engineer each crane for its particular needs and build into it those requirements necessary to do the job.

If YOU are planning to expand your capacity or facilities, a Browning engineer can put a 60-year background profitably to work for you. A copy of our comprehensive bulletin awaits your request.

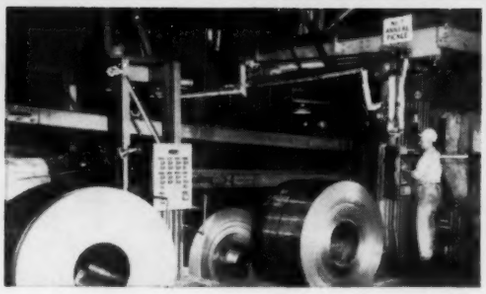
Cranes
•
Trolleys
•
Brakes
•
Hook Blocks
•
Buckets

VICTOR R. BROWNING & COMPANY, INC.

WILLOUGHBY (CLEVELAND), OHIO



Wichita Water Cooled Brakes *maintain exact tension* on No. 7 Annealing Line at Armco's Butler Works



P—A Automatic Tension Controller

Continuous service under exacting conditions of tension control are all in a day's work for the Wichita Water Cooled Brakes on this annealing line. Wichita Clutches and Brakes are used where the going is tough.

For difficult clutching and braking problems . . .

CONTACT YOUR NEAREST WICHITA ENGINEER

Clutch & Control Engineering Co., Livonia, Mich.
Fremont & Lewis, Inc., Cincinnati, Ohio
W. G. Kerr Company, Pittsburgh, Pa.
Clutch Engineering Co., Hartford, Conn.
Frank W. Yarline Co., Chicago, Illinois
Larry W. McDowell, Long Beach, California
Andrew T. Lobel, Denver, Colorado
Robert R. King Co., Cleveland, Ohio
Norman Williams, Houston, Texas
Sales Engineering Co., Salt Lake City 15, Utah
Allied Transmission Equipment Co., Kansas City 8, Missouri
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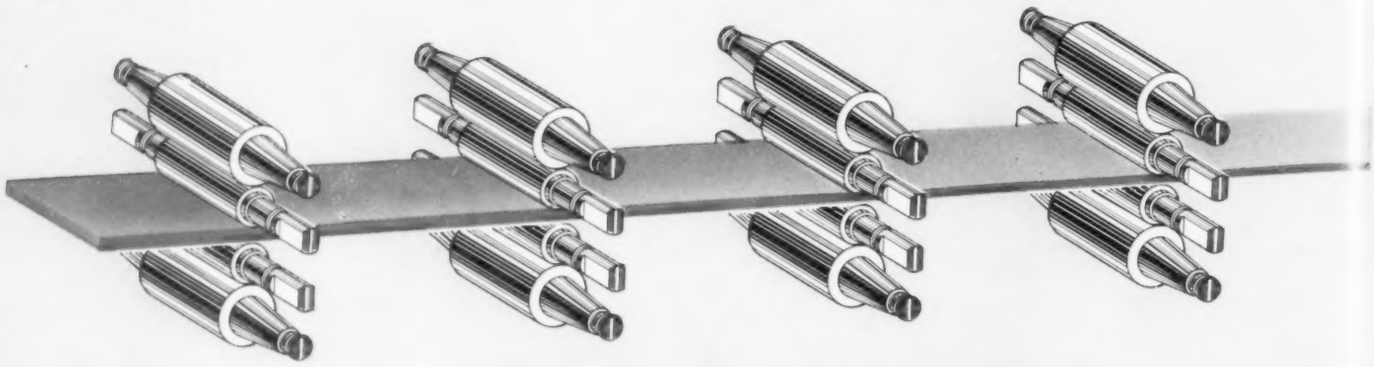
Malcolm S. Cone, Memphis, Tennessee
Dominion Power Press Equipment, Ltd. Burlington, Ontario, Canada
R. E. Kunz, Seattle 4, Wash.
Norman Rupp Co., Portland 4, Ore.
Bates Sales Co., St. Louis 1, Mo.
The Alfred Halliday Co., Lewisville, Kentucky, Atlanta, Birmingham, Knoxville, Sarasota

WICHITA Clutch COMPANY, INC.
WICHITA FALLS, TEXAS, U. S. A.

Write for Wichita General Catalog

(CONTINUOUS)



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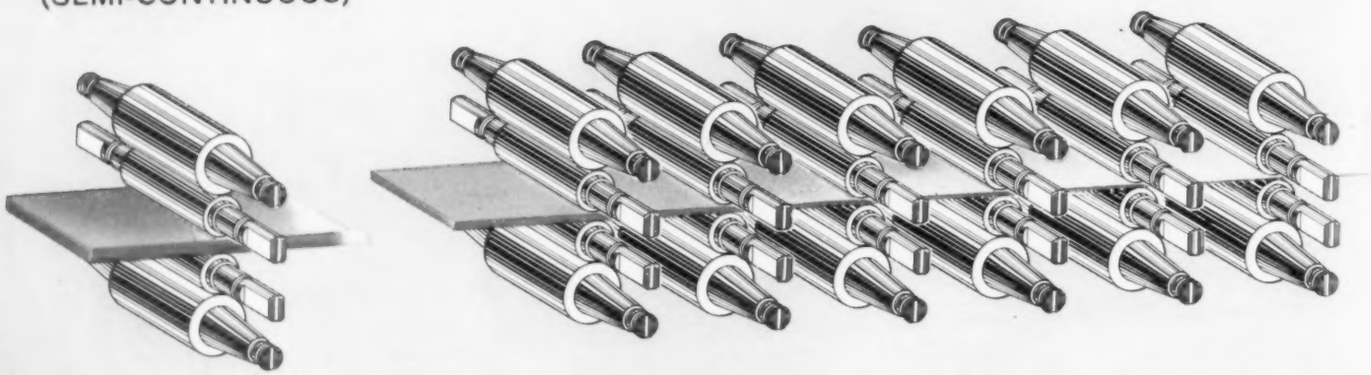


Mack-Hemp ***rolls are right for every mill...***

IN HOT STRIP MILLS...

These Mack-Hemp steel and iron rolls have met every test the nation's hot strip mills have put to them. They are:

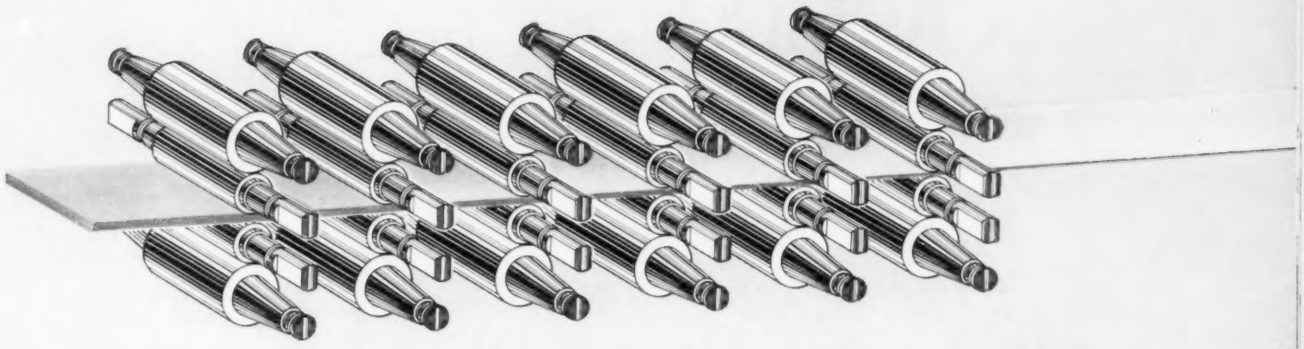
Technalloy... First heavy-duty cast alloy steel roll with high strength. An economical back-up roll for all 4-high stands, and a fine work roll in 2-high roughing stands.

Technikrome ... A high-carbon alloy steel roll of wide versatility. A good roughing stand work roll under average operating conditions.

Nichillite ... A definite chill alloy iron utility roll providing high hardness and wear resistance. Recommended for finishing work under good-to-average conditions.

Nironite A and AX... Nickel chromium alloy grain iron rolls with high strength and deep hardness penetration.

Nironite F... High alloy grain iron roll, double-poured for maximum core and neck strength, and specially heat treated to increase resistance to thermal shock and spalling.



KEY TO MODERN HOT STRIP ROLLING...

	CONTINUOUS		SEMI-CONTINUOUS	FINISHING TRAIN		
	Broadside Mill	Roughing Stands	Reversing Roughing Stand	Stands 1 & 2	Stands 3, 4 & 5	Finishing Stand
WORK ROLLS						
Good Conditions	Nironite AX 68 Shore	Nironite AX 68 Shore	Nironite F 68-72 Shore	Nironite F 74 Shore	Nironite F 78 Shore	#4 Nichillite 80 Shore
Average Conditions	Nironite A 65 Shore	Technikrome 40 Shore	Nironite F 68-72 Shore	Nironite F 74 Shore	Nironite F 78 Shore	#6 Nichillite 80 Shore
Severe Conditions	Technalloy 40-45 Shore	Technalloy 45 Shore	Technalloy 42-48 Shore	Superalloy 48-50 Shore	Nironite F 78 Shore	Nironite F 80 Shore
BACK-UP ROLLS (in 4-HI STANDS)	Technalloy 48 Shore	Technalloy 48 Shore	Technalloy 48 Shore	Technalloy 48 Shore	Technalloy 48 Shore	Technalloy 48 Shore

Midland Superalloy . . . A nickel-chromium-molybdenum alloy steel roll especially developed to withstand fire cracking and breakage under severe operating conditions.

• • •

In short, there is a Mack-Hemp roll that is just right for each stand and each set of operating conditions. This tailoring of the rolls to the mill is one of the important reasons why *you get more tonnage from the rolls with the striped red wabblers.*

MACKINTOSH-HEMPHILL

DIVISION OF

E. W. BLISS COMPANY

Pittsburgh and Midland, Pa.

MACKINTOSH-HEMPHILL DIVISION · PITTSBURGH U.S.A. · BLISS

Mackintosh-Hemphill Division of E. W. Bliss Co. is proud to be numbered among the suppliers of Armco Steel Corporation's Butler Works

at ARMCO HOT or COLD steel

is identified with

Markal® Paintstik MARKERS

Marking identification numbers on hot coils immediately after leaving coiler, above 1200°F.

Worker uses Markal Paintstik to mark code and identification numbers on cold, oily steel.

ARMCO STEEL CORPORATION uses both hot surface and cold surface Markal Paintstik Markers at their Butler Works. Type "H-T" is ideal for temperatures from 250°F. to 1800°F., will not run, char, peel or crack. Type "B" is used on oily coils, their identification being retained at cold and warm temperatures up to 250°F. Such diverse applications are typical of the wide range of possibilities available from the complete line of Markal Paintstik Markers . . . 16 types to meet all your requirements.

WRITE TODAY for complete Markal literature. Free!

MARKAL COMPANY

3087 West Carroll Avenue • Chicago 12, Illinois

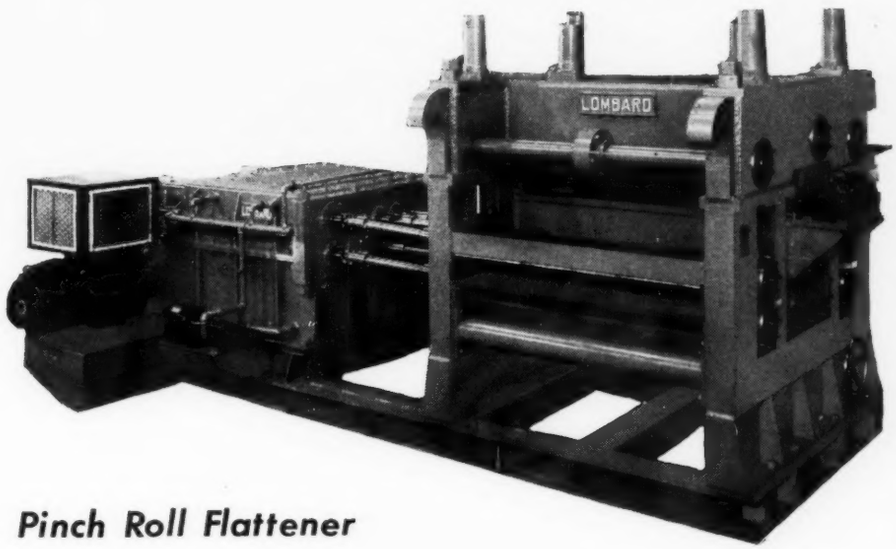
MARKAL . . . The Mark of Quality

LOMBARD'S LATEST

EQUIPMENT FURNISHED FOR ARMCO'S BUTLER WORKS No.4 ANNEAL AND PICKLE LINE

- -Expanding Cone Uncoiler
- -Coil Stripper
- -Coil Box
- -Pinch Roll Flattener
- -Three Roll Tension Unit
- -Two Roll Tension Bridle
- -Tension Reel
- -Coil Car

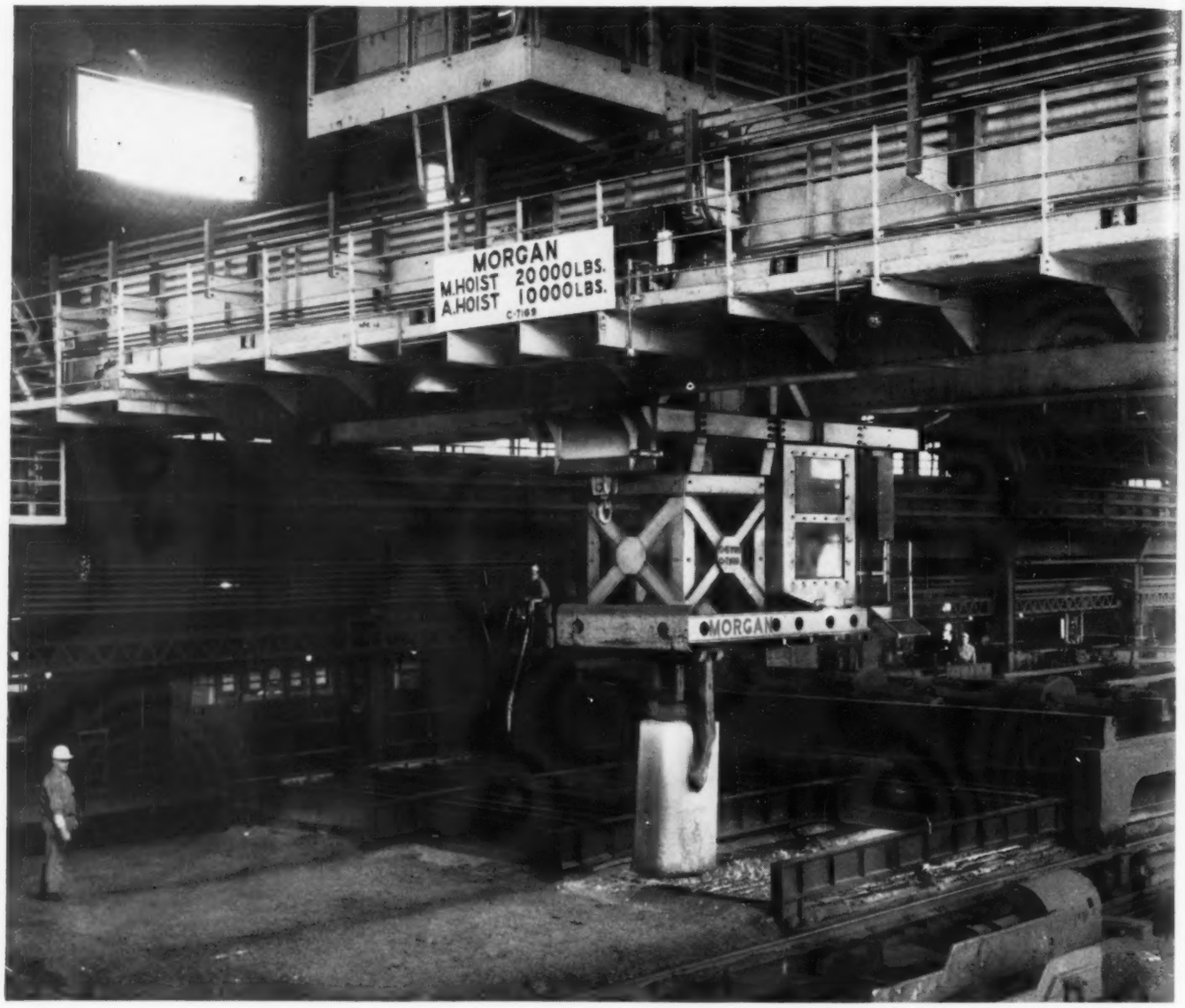
SATISFIED USERS LOMBARD ROUND THE WORLD



Pinch Roll Flattener

LOMBARD CORPORATION • 639 WICK AVE. • YOUNGSTOWN, OHIO

DESIGNERS AND PRODUCERS OF HEAVY EQUIPMENT FOR THE METAL INDUSTRY



10/5 Ton, 78' 0" span, Soaking Pit Crane

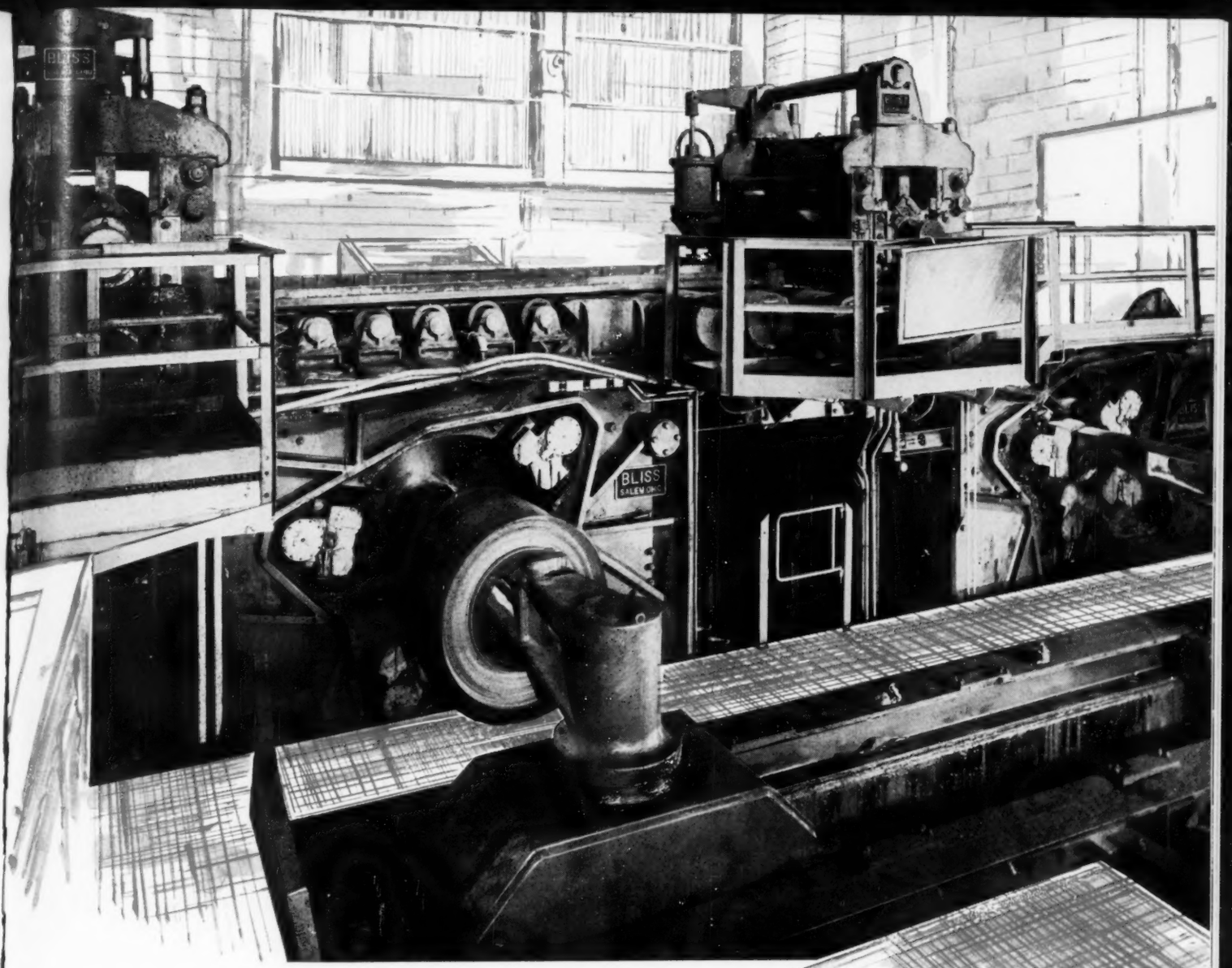
Armco-Butler moves with Morgan cranes...

From scrap to finished steel, Morgan cranes and mill machinery keep metal on the move. This soaking pit crane is a vital link in the production chain at the Butler, Pennsylvania Works of Armco Steel Corporation. Ingots are moved quickly, efficiently. Operating and maintenance costs are kept to a minimum.

Where your metal handling calls for top reliability to keep production flowing, call the Morgan representative. He'll advise you on the most economical equipment for your purposes.

THE MORGAN ENGINEERING CO. *Alliance, Ohio*

Overhead electric traveling cranes, gantry cranes, open hearth special cranes, blooming mills, structural mills, shears, saws, auxiliary equipment and welded fabrications.



FROM MILD STEEL TO STAINLESS

It's all the same to these two Bliss coilers at Armco

These smooth-running Bliss downcoilers on the new 56" hot strip mill at Armco Steel Corporation's Butler, Pa. Works, coil everything from flexible mild steel to tough, springy stainless steel strip. Bliss coilers, with their expanding mandrels and positive wrapping action were used because of the variety of gages and alloys to be put through the new mill. In the Bliss design, the mandrel keeps the strip in tension during coiling; wraps a tight, smooth-edged coil without surface scratches or marks. Blocker rolls retract as soon as leading end has been snubbed on the mandrel, and don't move in again until the trailing end is coming through the pinch rolls.

Besides the two downcoilers, Bliss' Rolling Mill Division designed and built the 100-yard-long runout table as another contribution to the Butler Works' handsome new hot strip line. For other examples of Bliss engineering for the ferrous and nonferrous industries, why not write for a free copy of the new profusely illustrated 84-page Bliss Rolling Mill Brochure, Bulletin 40-B? It describes the operation of Bliss mills and auxiliary equipment.

BLISS
SINCE 1857 ®

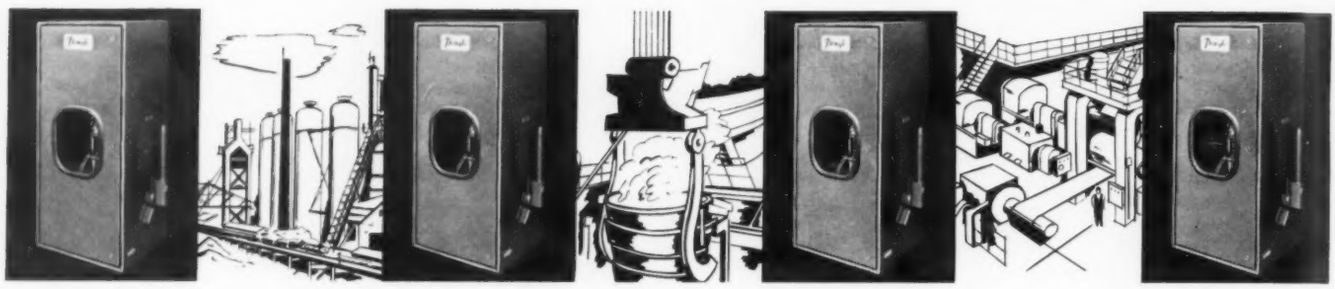
Bliss is more than a name . . . it's a guarantee

E. W. BLISS COMPANY, Rolling Mill Division, Salem, Ohio

Subsidiary: The Matteson Equipment Company, Inc., Poland, Ohio

Rolling Mill Division of E. W. Bliss Company is proud to be numbered among the suppliers of Armco Steel Corporation's Butler Works

Pringle Switches—Keeping the Power In Line



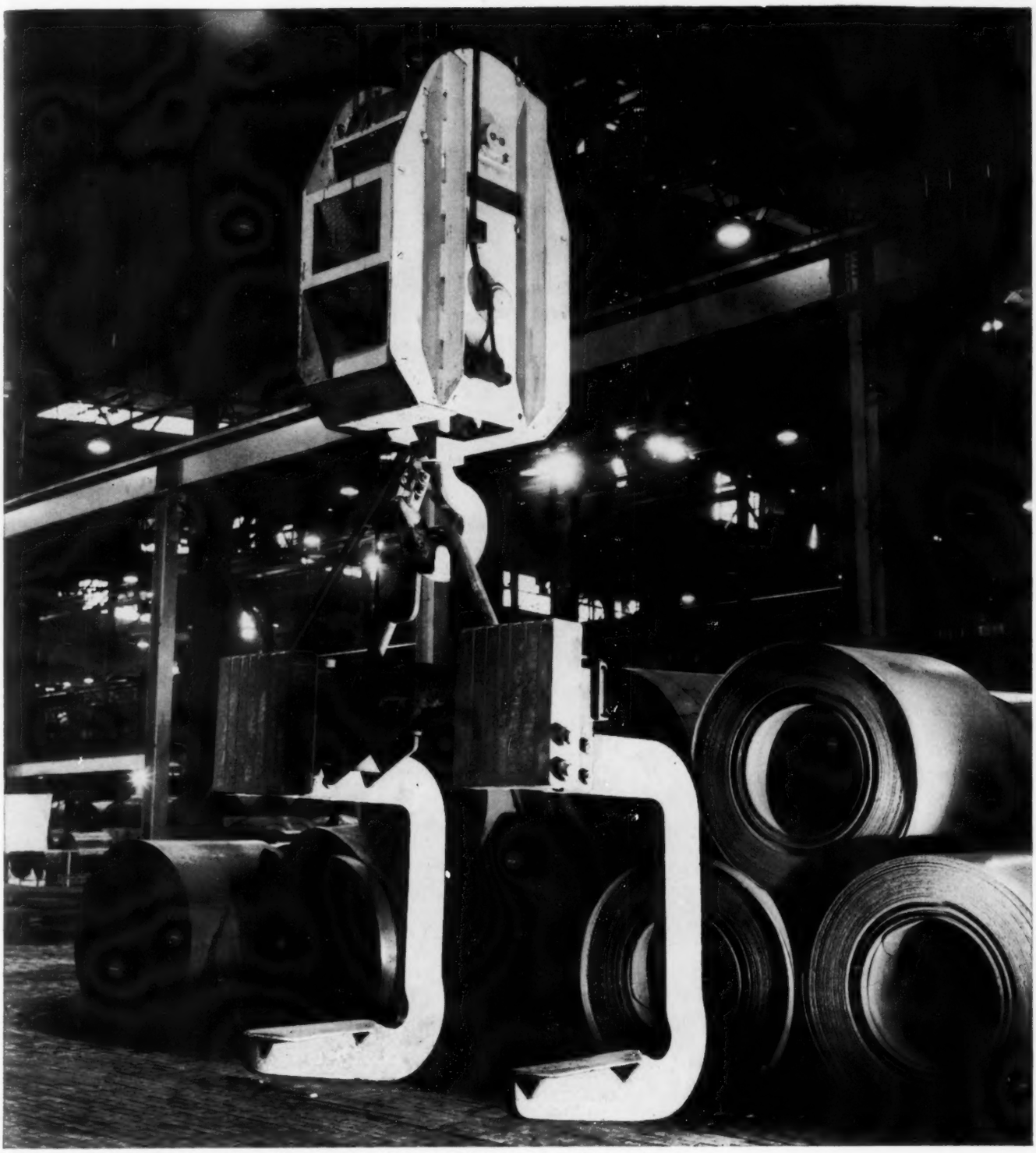
at Butler Works of Armco Steel

In the high-powered, fast-moving steel industry it's important to be sure of switch performance.

The Pringle Switch with "BOLTED" Pressure silver contacts is proving its worth every day at Armco Steel. The Pringle switch is so designed that it operates quickly and easily under *all* conditions. Maximum *bolted* pressure is exerted on the closed contacts with minimum physical effort.

The Pringle "BOLTED" Pressure Silver Contact Switch has piled up an unbeaten reliability record in hundreds of top-flight industrial assignments. Our literature tells the whole story —it's yours by return mail. Pringle Electrical Manufacturing Company, 1904 North Sixth Street, Philadelphia, Pa.

Pringle



Heppenstall Motorized Rotating Crane Hook, with aid of double "C" hook, lifts, rotates and positions coils of strip steel in hot coil storage shop of Butler, Pa., Works, Armco Steel Corporation.

IN ARMCO'S BUTLER WORKS many types of Heppenstall hooks, tongs and sheet lifters are handling material safely, quickly and efficiently. Heppenstall scrap chopper knives have increased production life to 18 to 20 turns, compared with 4 to 10 turns with the knives formerly used for this work. For more information about Heppenstall products—used from melt shop to finished product throughout the steel industry—call your Heppenstall Representative or write us direct.

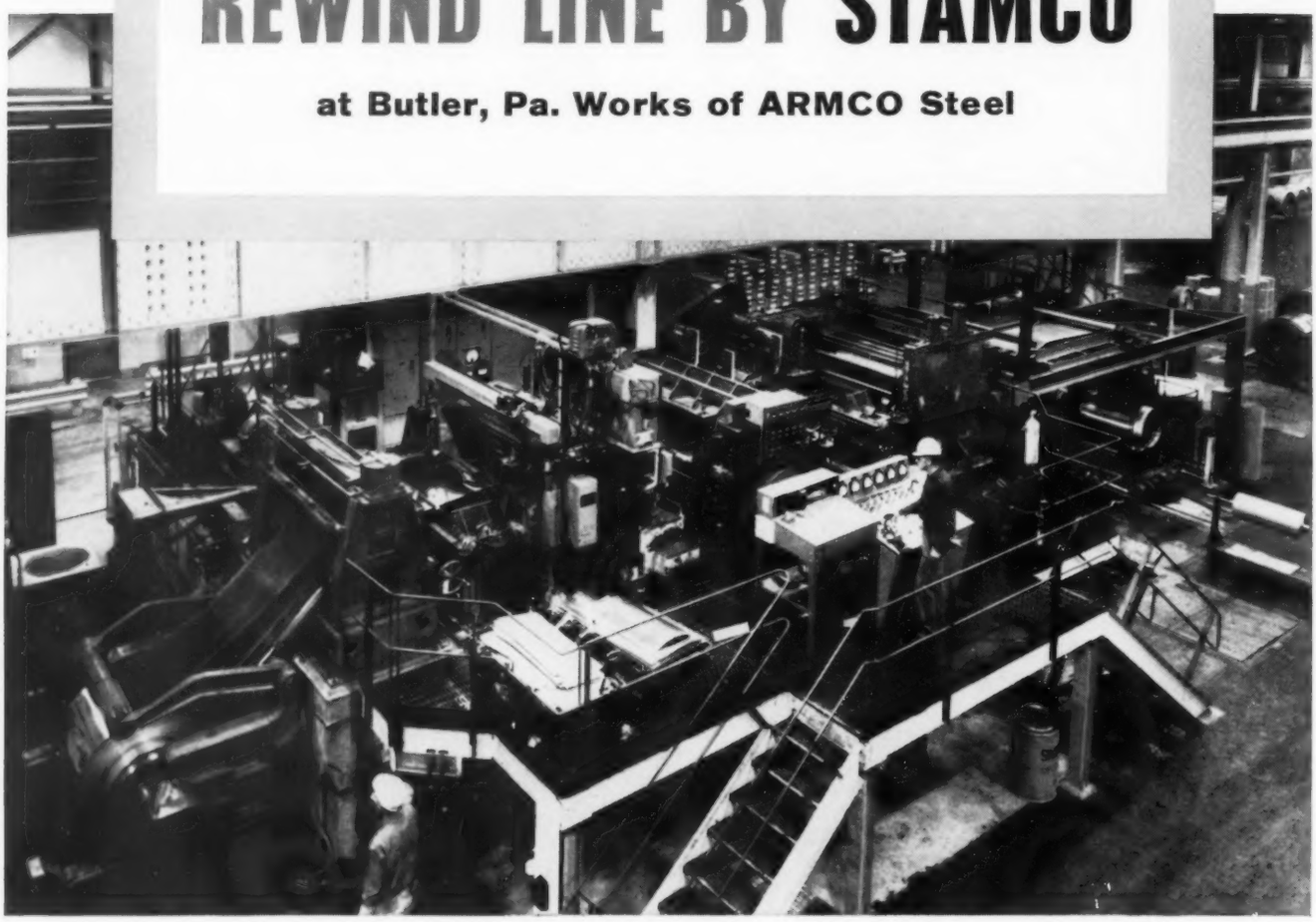
H
M H

HEPPENSTALL COMPANY • PITTSBURGH 1, PA.
Plants: Pittsburgh & New Brighton, Pa. • Bridgeport, Conn.

MIDVALE-HEPPENSTALL COMPANY • NICETOWN, PHILADELPHIA 40, PA.

STAINLESS STEEL REWIND LINE BY STAMCO

at Butler, Pa. Works of ARMCO Steel



Line is used as a preparatory line of "Z"-mill. Coils are wound on special mandrel. End strips can be welded to stainless steel coils to enable rolling to the end of stainless material. After rolling, they are rewound in reverse procedure with the ends cropped out. This frees "Z" mandrel and coils are now ready for further processing. Line consists of two unwinders, flattener, crop shear, welder, pinch roll and "Z" mandrel winder.

STAMCO, INC., NEW BREMEN, OHIO

District Offices Stamco Sales, Inc.

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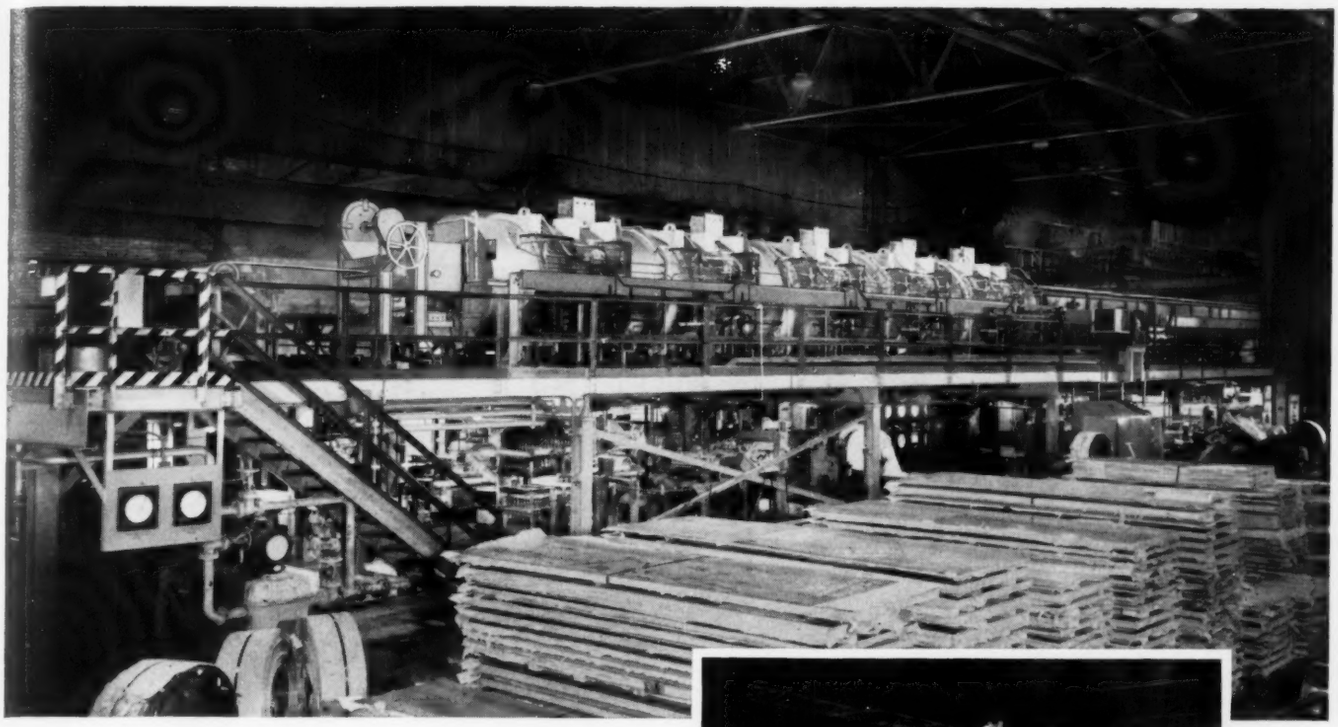
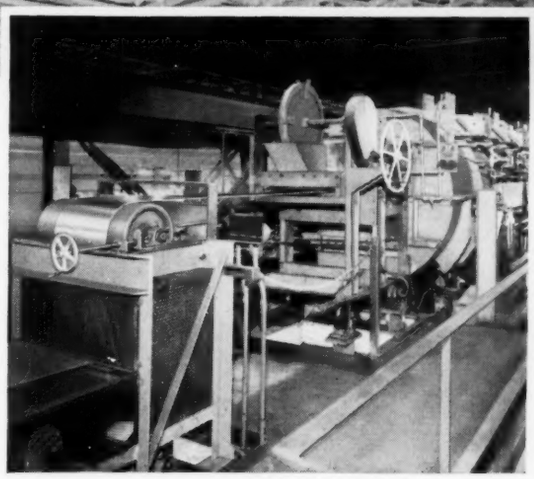
R. P. Popp, 101 Investment Building, Pittsburgh 22, Pa.
I. W. Spraitzar, 159 Main Street, Chatham, New Jersey
W. E. Heineman, 122 West Burlington Ave., LaGrange, Illinois
W. H. Millan, 11955 Shaker Boulevard, Cleveland 20, Ohio





EF Furnace
Bright Annealing Stainless Strip at Armco Steel

• The No. 18, 24" wide Stainless Strip Bright Annealing Line at Armco's Butler, Penna. Works, pictured above, is one of 25 coating, silicon and bright annealing lines, designed and built by The Electric Furnace Co., installed in various Armco plants. Like several other EF horizontal bright annealing lines, the furnace and cooling sections are mounted on a balcony. This permits the pay-off reel, coiling reel and control equipment to be installed under the furnace, saving floor space and minimizing building changes.

EF Stainless Strip Bright Annealing Furnaces produce a durable, mirror finish on trim stock and other stainless strip *without chrome depletion*. The Electric Furnace Co. has designed and built *23 stainless strip bright annealing lines;* this is more than any other manufacturer. Included are both horizontal and vertical type furnaces, fuel fired and electrically heated.

For the highest finish, the most durable corrosion resistant surface, and the most experience in bright annealing stainless strip, you too will find that "it pays to call the EF furnace engineers".

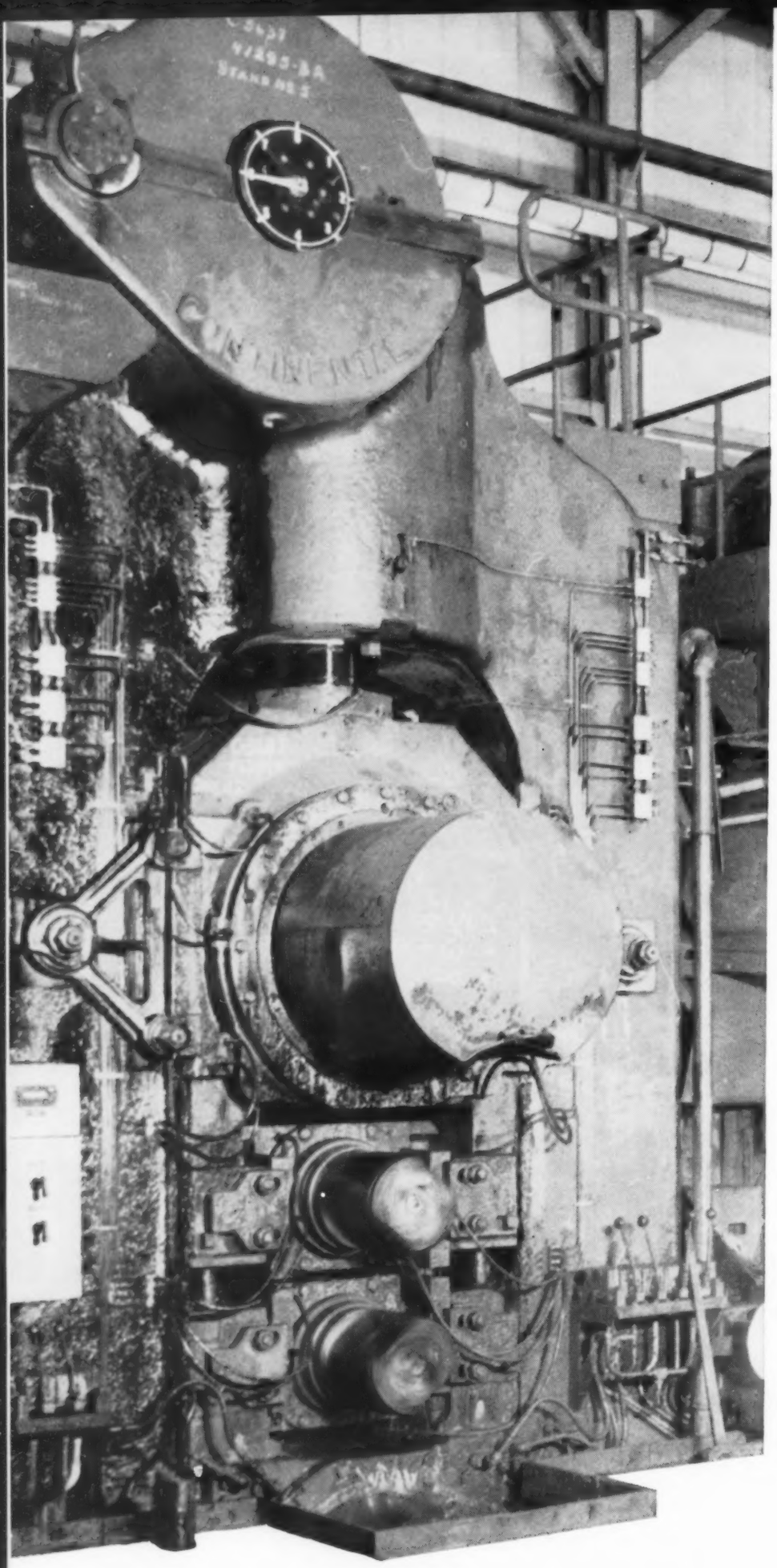
THE ELECTRIC EF FURNACE CO.
GAS • OIL • ELECTRIC

THE ELECTRIC FURNACE CO.

Fuel Fired and Electrically Heated
HEAT TREATING FURNACES
for Processing any Product, in any Atmosphere, any Hourly Output Required

Salem - Ohio

SUBSIDIARIES—Turnkey Engineering Co., Inc., South Gate, Cal. • Canefco Limited, Scarborough, Ontario
SALES REPRESENTATIVES—2842 West Grand Blvd., Detroit 2, Mich. • also 968 Coleman Rd., Cheshire, Conn.

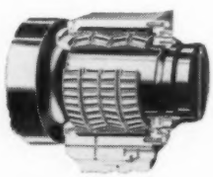


ARMCO specifies tapered roller bearings for their hot strip mill back-up rolls

Armco's 25″ & 54″ x 58″ five stand tandem hot strip mill installed in 1955 at their Butler, Pa., plant has operated without the loss of a single tapered roller back-up roll bearing. And operating expenses have been low on lubrication system maintenance and cost of lubricant. Mill downtime due to failure of bearings and lubricating system is non-existent.

Along with economy, tapered roller bearing equipped back-up rolls have provided a number of other positive benefits. They maintain accurate strip gage through positive roll location and there is minimum slippage and wear on mill rolls because of lower starting torque. Tapered roller bearings provide higher momentary overload capacity.

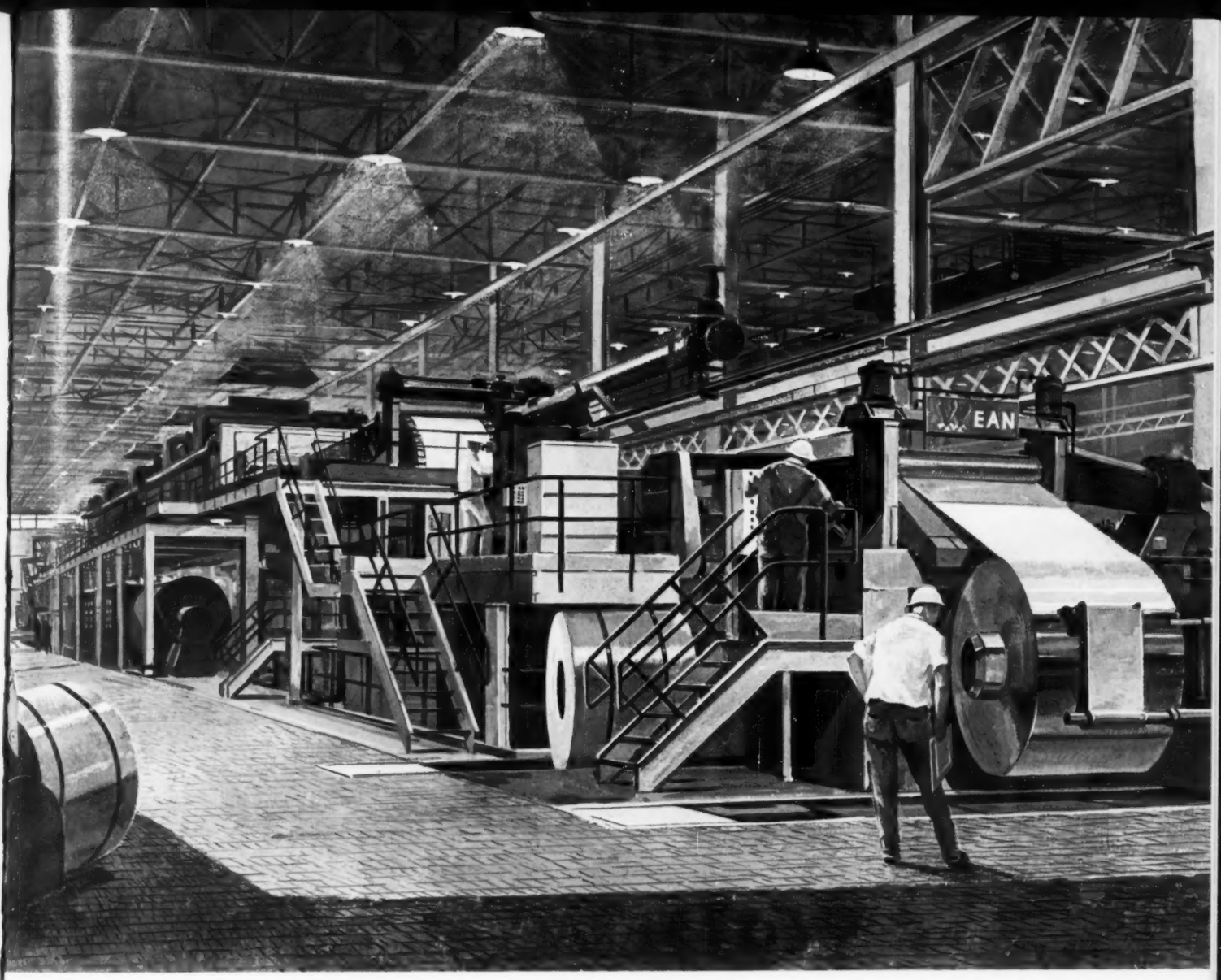
For the most in bearing performance and engineering service when you buy or build a mill, specify Timken® bearings. The Timken Roller Bearing Company, Canton 6, Ohio. Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits. Canadian Division: Canadian Timken, St. Thomas, Ontario.



Industry rolls on

TIMKEN®

tapered roller bearings



PORTRAIT OF PROGRESS: *Wean Annealing and Pickling Line at Armco Steel Corporation's Butler Works*

Wean Line Part of Armco's Expansion into Wider, Closer Tolerance Stainless

Over the past ten years, Armco Steel Corporation has carried on a multi-million dollar expansion and modernization of its Butler, Pennsylvania plant facilities. One of the latest projects boosts the plant's production of flat-rolled stainless steel, providing customers with wider, closer tolerance stainless sheet and coils.

A vital part of this program is represented by the Wean stainless annealing and pickling line illustrated. This line is unique, in that all processing sections are installed above floor level. Above-ground design facilitates inspection and maintenance of the furnace section, acid tanks, and drive mechanisms.

Armco's new Wean line is capable of handling 30,000-pound stainless steel coils from 24″ to 52″ in width and from .010″ to .080″ in thickness. The line operates at speeds up to 150 feet per minute. An even flow of materials is maintained in the processing section by two pay-off reels that permit rapid joining of coils.

The Wean "creative engineering" that resulted in these new design features has also been part of the development of annealing facilities for every major steel producer. This background of research and development is ready to help you solve your production and modernization problems.

THE WEAN ENGINEERING COMPANY, INC. · WARREN, OHIO

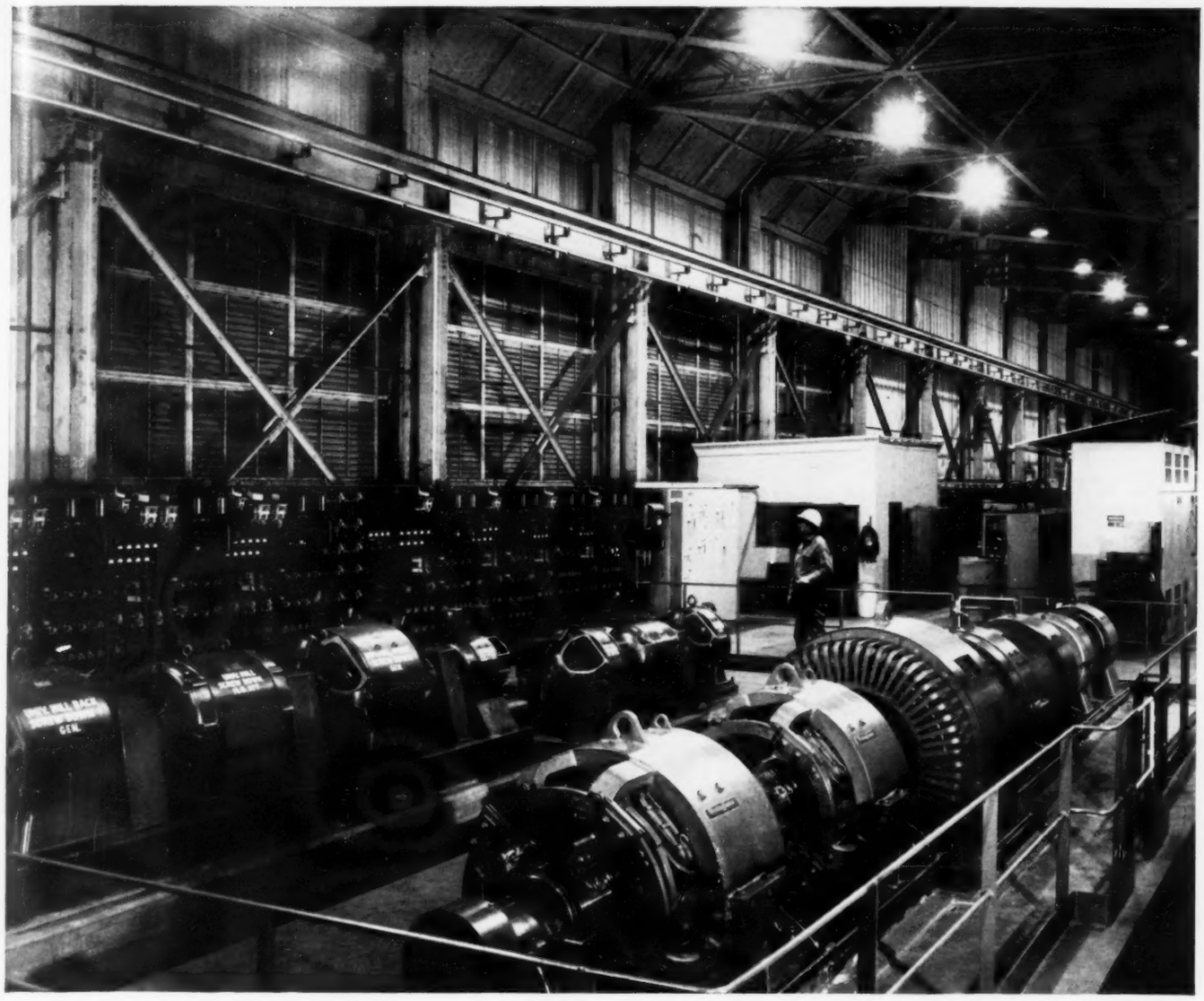
Complete coal carbonization plant built for Armco Steel Corporation by Wilputte Coke Oven Division. Plant consists of coal and coke handling facilities, a battery of 76 under-jet coke ovens, and complete coal chemical recovery facilities.

Allied Chemical

BASIC TO AMERICA'S PROGRESS

WILPUTTE COKE OVEN DIVISION

40 RECTOR STREET, NEW YORK 6, N. Y.



Clean air by AAF protects this vital equipment for Armco

Dust and dirt never get a chance to cause damage in the motor room of Armco Steel's Butler Works. Several different types of AAF air filters are at work here, keeping it spotless 'round-the-clock. High-efficiency, self-cleaning AAF Roll-O-Matic and Multi-Duty filters guarantee a continuing supply of clean air for the electrical equipment. Only maintenance ever required by the Roll-O-Matic is once-a-year replacement of Roll-O-Mat media (simple as changing film in a camera); and periodic removal of sludge is all the attention ever given the Multi-Duty.

Elsewhere at this Armco mill AAF equipment is serving other special needs. Dust control units are installed in the hot-strip mill and the pickling line . . . and AAF intake filters are protecting Armco's large engines and compressors.

Make sure you get clean air that's engineered for your specific needs. Talk with the *one* company that makes *all kinds* of air filters—AAF. For more information contact your local AAF representative or write us direct. Address: Robert Moore, American Air Filter Company, Inc., 302 Central Avenue, Louisville, Kentucky. In Canada: American Air Filter of Canada, Ltd., 400 Stinson Blvd., Montreal 9, Quebec.

AAF **American Air Filter**

BETTER AIR IS OUR BUSINESS

AFI MEMBER

Greetings to Armco's Butler Works

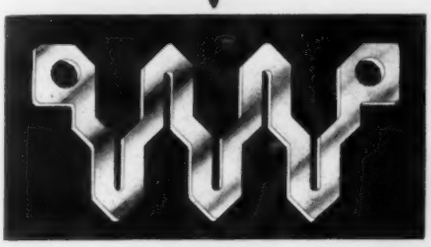
--a good friend
and a good customer

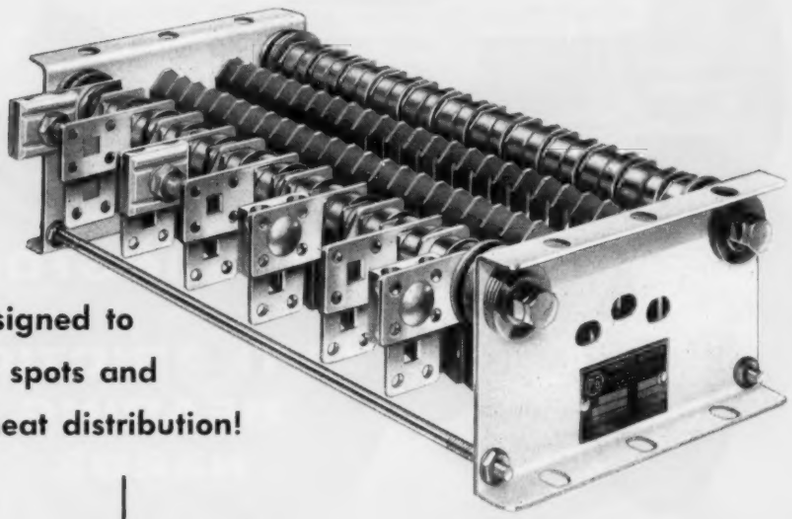
Here's a man who's ready to help you with a roll problem

But you don't need to have a roll problem to have a visit from Bill Curran, General Manager at National Roll. To the contrary, the "boss" spends a lot of his time with customers discussing their operations and roll requirements before problems have an opportunity to develop. This is typical of the personal interest National takes in helping customers get the benefits of maximum roll performance. For personal attention to *your* roll requirements, whether steel, iron or nodular iron, order from National. You'll see why . . . NATIONAL'S THE GROWING NAME IN ROLLS.

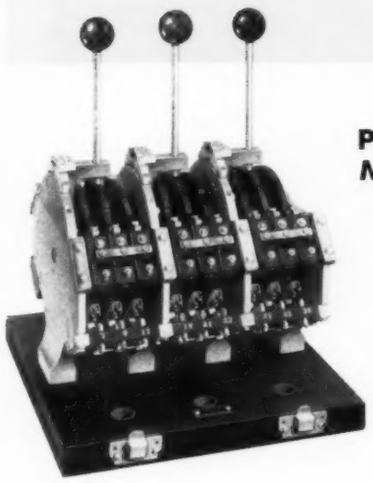
NATIONAL ROLL & FOUNDRY DIVISION
GENERAL STEEL INDUSTRIES, INC., Avonmore, Pennsylvania
General Steel Industries, Inc., General Offices: Granite City, Ill. Plants: Granite City, Ill., Eddystone, Pa., Avonmore, Pa.
Subsidiary: St. Louis Car Company, St. Louis, Mo.

Ventilation *is the HEART of any Resistor...*





P-G GRID . . . designed to eliminate hot spots and insure even heat distribution!



P-G *Improved* **Master Switch**

Lighter in weight
Easier to wire

Type MD for general application in Mill Service

Each single Master has a maximum of 12 circuits and up to 6 points either direction. One to four switches in a single enclosure saves valuable mounting space. Overall length less than 22" on four unit switch. Short lever travel. Self-lubricating bearings. Fine silver double break contacts. Spring return (optional). Enclosure easily removed.

Write for Bulletin No. 410

Longer resistor life depends on adequate ventilation and how efficiently heat is dissipated. P-G grid design equalizes the amount of air space surrounding each leg or loop to obtain even heat thruout the grid area . . . note illustration.

Compare P-G with any other punched steel grid resistor — you will find more air space is provided. This produces better ventilation — longer resistor life and over twenty-five years of use in steel mill service has proven this.

For the maximum in resistor value, try P-G the ORIGINAL Steel Grid Resistor.

Write for Bulletin No. 500

These P-G products are used in the Butler Works of Armco Steel Corporation.

Established 1892

THE **POST-GLOVER** ELECTRIC COMPANY

OFFICE and FACTORY—Kenton Lands Road, Erlanger, Kentucky

MAILING ADDRESS—Box 709, Covington, Kentucky

Choosing *exactly* the right bearing can mean a vital difference in performance, cost and product life. That's why it pays to call Torrington first.

Torrington makes *every* basic type of anti-friction bearing . . . can advise you *impartially* on the best bearing for *your* application. Needle, roller or ball . . . you won't find finer bearings than Torrington. Specify with confidence. If you have a bearing problem, call or write us today. Send for catalog information.

1. Drawn Cup Needle Bearing. Maximum radial capacity in minimum cross section. Easily positioned by press fit. **2. Drawn Cup Roller Bearing.** Ample lubricant storage for smooth starting, cool running, extra-long service life. **3. Heavy Duty Roller Bearing.** Top bearing efficiency and long life under toughest shock conditions. **4. Roller Thrust Bearing.** Precision built for outstanding performance. Large Controlled Contour rollers for maximum capacity. **5. Self-Aligning Ball Bushing.** Low cost unit for top performance in rugged applications. **6. Spherical Roller Bearing Pillow Block.** High radial and thrust capacity. Fast, easy installation. Grease or oil-bath lubrication. **7. Needle Thrust Bearing.** Unequalled capacity for size and weight. Runs directly on hardened ground surfaces, or on standard thrust races. **8. Cam Follower.** Exceptional combination of high capacity, maximum toughness, dependable performance under shock loads. **9. Spherical Roller Bearing.** Precision engineered for maximum efficiency, optimum service life. Self-aligning.

progress through precision **TORRINGTON BEARINGS**

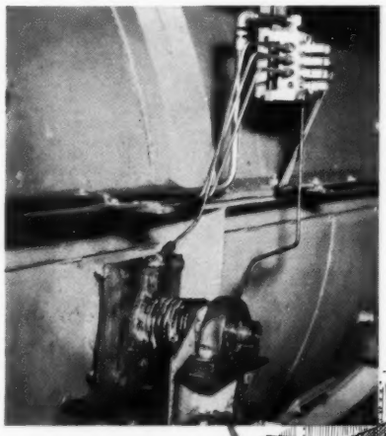
THE TORRINGTON COMPANY Torrington, Connecticut • South Bend 21, Indiana

TRABON®

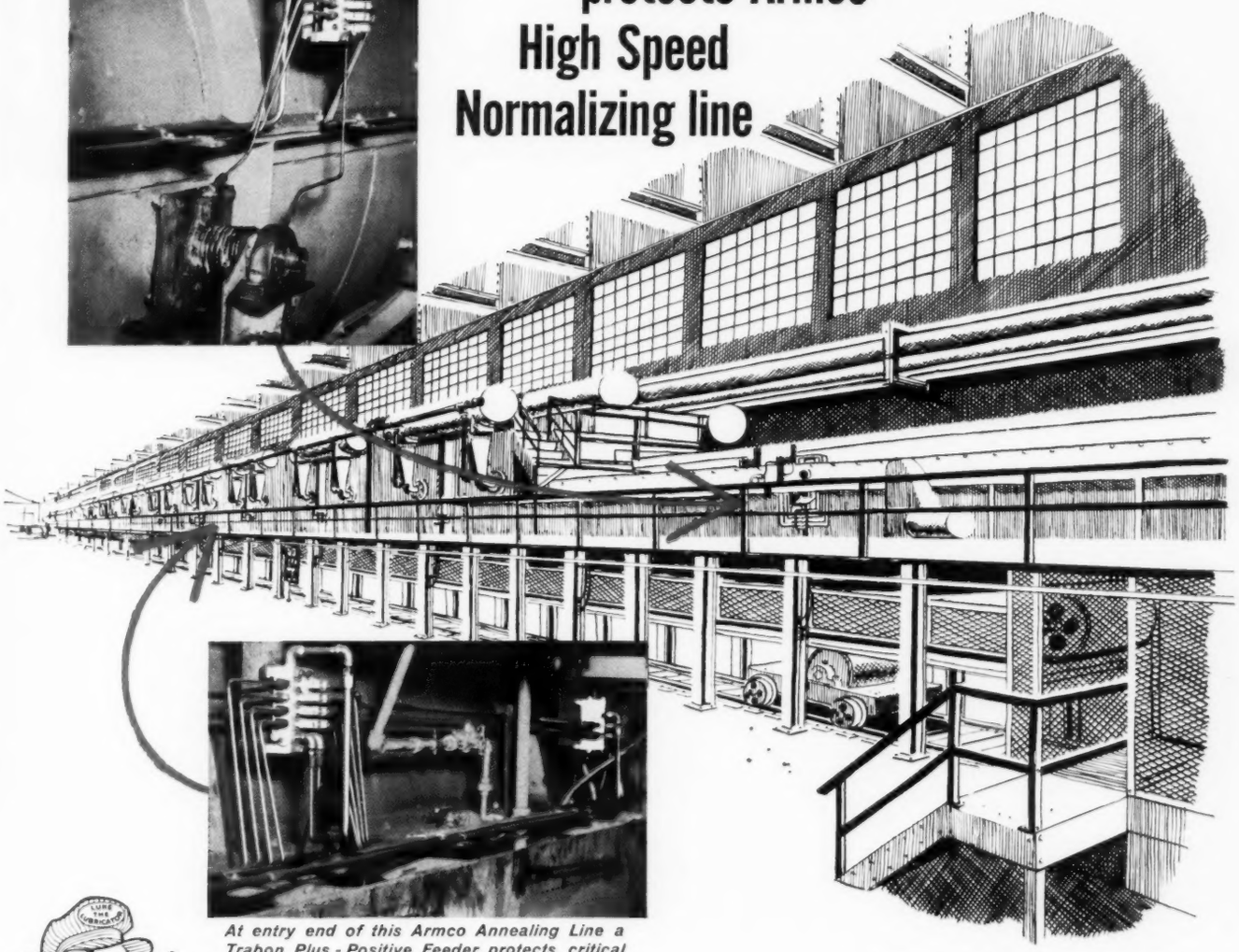
CENTRALIZED LUBRICATING SYSTEMS

At Armco Steel's Butler Works, Number 7 is an extremely long, high speed normalizing line. Until Trabon's new multizoned system, lubricating long expanses of equipment economically had always been a problem. Now, four lubricating zones serving a total of 238 bearing points are served from a **single air operated barrel pump** working through **a single main pressurized header line.** Armco saves on auxiliary pumps and reservoirs and the man hours it takes to keep them supplied. Trabon Centralized Lubricating Systems provide the exact amount of lubricant your bearings need and watch over them by means of a central warning system. See why the most modern and automated steel making facilities today use Trabon. Write for technical details.

A Trabon Plus - Positive Feeder receives lubricant from a single pressurized line — force-feeding exact quantities to bearings in the preheat zone.



Trabon "zoned" automatic lubrication protects Armco High Speed Normalizing line



At entry end of this Armco Annealing Line a Trabon Plus - Positive Feeder protects critical bearings operating under high temperatures.

Write for new Trabon General Catalog.

PLUS POSITIVE "*Centralized*" OIL AND GREASE SYSTEMS "*Meterflo*" CIRCULATING OIL SYSTEMS "*Meter-Mist*" OIL SYSTEMS

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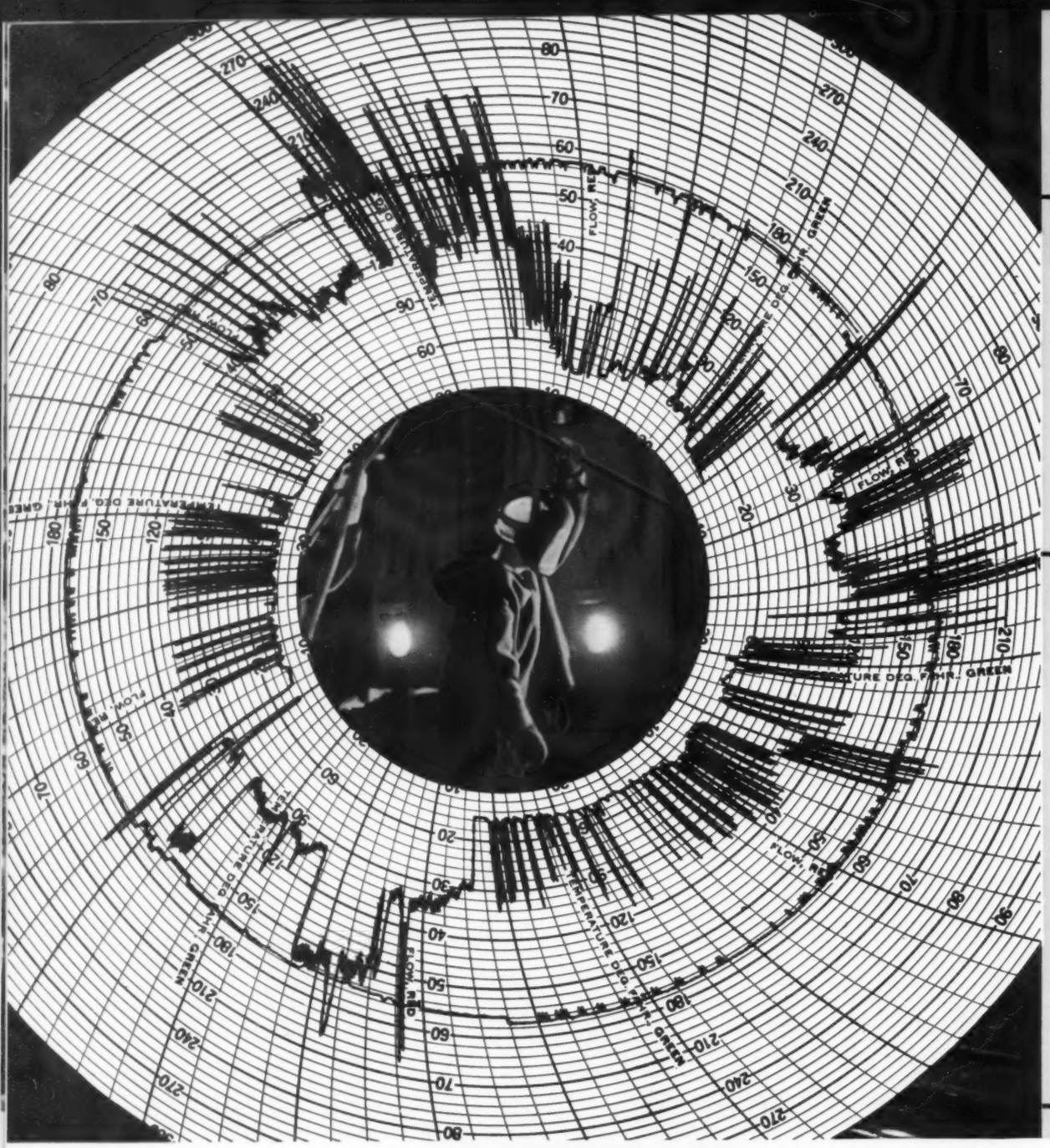

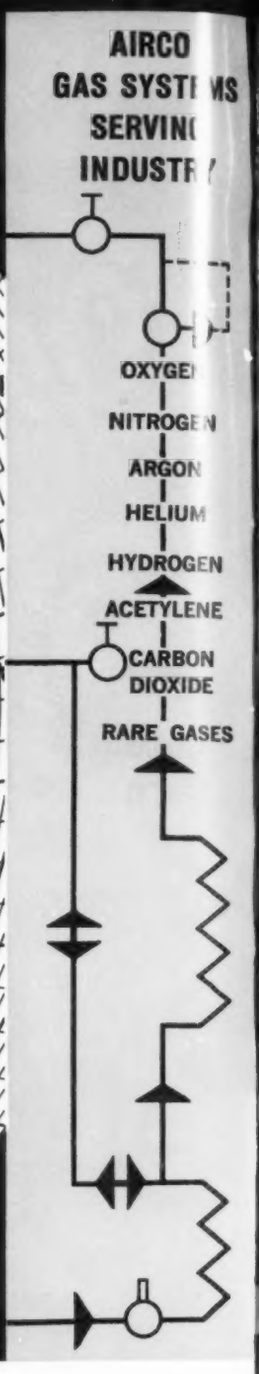

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Aerial view of Pittsburgh's Golden Triangle, with Point State Park in the foreground.

Association of Iron and Steel Engineers

1961 Annual Convention

HOTEL PENN-SHERATON PITTSBURGH, PA.

SEPTEMBER 25, 26, 27, 28

PROGRAM

Association of Iron and Steel Engineers

1961 Annual Convention

HOTEL PENN-SHERATON PITTSBURGH, PA.

SEPTEMBER 25, 26, 27, 28

MONDAY, SEPTEMBER 25

9:00 am—REGISTRATION—
Fort Duquesne Room

9:15 am—BUSINESS MEETING—
Urban Room

Conducted by President C. E. Pritchard

9:30 am—ELECTRICAL SESSION—
Urban Room

Chairmen: John F. Kostelac, Division Superintendent, Maintenance, Midland Plant, Crucible Steel Co. of America, Midland, Pa.

James A. B. Pinney, Assistant Chief Engineer, Alan Wood Steel Co., Conshohocken, Pa.

"Recent Developments and Operating Experience in Control of Gage and Set Up of Strip Mills," by R. E. Marrs, Consulting Application Engineer, Metal Rolling Application Engineering, General Electric Co., Schenectady, N. Y.

"On-Line Computer Control for a Reversing Plate Mill," by A. W. Smith and L. P. Gripp, Industrial Engineering Dept., Westinghouse Electric Corp., East Pittsburgh, Pa.

"Controls and Instrumentation for New Sinter Plant," by W. J. Tunny, Superintendent, Electrical Maintenance, The Youngstown Sheet and Tube Co., East Chicago, Ind.

9:30 am—JOINT IHEA AND AISE SESSION ON CONTINUOUS FURNACE PROCESSING—
Monongahela Room

Chairmen: Hugh J. Pugsley, Senior Vice President, Swindell-Dressler Corp., Pittsburgh, Pa.

C. H. Vaughan, Assistant Vice President, The Electric Furnace Co., Salem, Ohio

"Continuous Strip Annealing," by W. P. Gill, Marketing Specialist, Industrial Heating Dept., General Electric Co., Shelbyville, Ind.

"Continuous Heat Treatment of Steel Plate," by N. K. Willis, Director of Engineering, Drever Co., Bethayres, Pa.

"Continuous Strip Galvanizing Development," by Carroll Cone, Vice President—Engineering, Surface Combustion Div., Midland-Ross Corp., Toledo, Ohio

2:00 pm—OPERATING PRACTICE SESSION—
Urban Room

Chairmen: W. A. Black, Assistant Director of Research, Electromechanical Research Center, Republic Steel Corp., Cleveland, Ohio

A. B. Glossbrenner, General Foreman, The Timken Roller Bearing Co., Canton, Ohio

"Continuous Galvanizing Practices and Trends," by Dean W. Ferguson, General Foreman, Galvanizing, Pittsburgh Works Div., Jones & Laughlin Steel Corp., Pittsburgh, Pa.

"Recent Developments in Strip Thickness Control," by I. G. Orellana, Head, Measurement & Control, Electromechanical Research Center, Republic Steel Corp., Cleveland, Ohio

"Strip Processing," by Donald A. McArthur, Vice President—Engineering, The Wean Engineering Co., Inc., Warren, Ohio

2:00 pm—LUBRICATION SESSION—
Monongahela Room

Chairmen: A. E. Cichelli, Lubrication Engineer, Construction Engineering Dept., Bethlehem Steel Co., Bethlehem, Pa.

C. E. S. Eddie, Plant Lubrication Engineer, Great Lakes Steel Corp., Div. of National Steel Corp., Ecorse, Mich.

"Crane Rail Lubrication," by Elmer E. Fleck, President, and Hugh L. Davis, Sales Engineer, Research Appliance Co., Allison Park, Pa.

"Effect of Fire-Resistant Fluids on Design and Operation of Hydraulic Systems," by William M. Schrey, Field Lubrication Engineer, National Tube Div., United States Steel Corp., Pittsburgh, Pa.

"The Selection and Evaluation of Rolling Oils," by R. W. Kenyon, General Sales Manager, Kerns United Corp., Chicago, Ill.

TUESDAY, SEPTEMBER 26

9:00 am—ELECTRICAL SESSION—
Urban Room

Chairmen: Elmer E. Barthel, Assistant Superintendent—Maintenance, Pittsburgh Steel Co., Monessen, Pa.

Clayton L. Squier, Assistant Electrical Superintendent, Bethlehem Steel Co., Lackawanna, N. Y.

"Electrical Protection on High Capacity Systems," by Paul S. Potter, Electrical Engineer, Bussmann Manufacturing Div., McGraw-Edison Co., St. Louis, Mo.

"Application of Circuit Breakers with Symmetrical Ratings in Steel Mills," by Philip L. Camp, Manager, Low Voltage Engineering, I-T-E Circuit Breaker Co., Philadelphia, Pa.

"Electrical Lockout Procedures," by J. R. Lamberton, Electrical Engineer, National Tube Div., United States Steel Corp., Pittsburgh, Pa.

9:00 am—COMBUSTION SESSION—
Monongahela Room

Chairmen: C. W. Dunn, Superintendent Utilities, Fairless Works, United States Steel Corp., Fairless Hills, Pa.

F. C. McGough, Superintendent, Fuel and Power, The Youngstown Sheet and Tube Co., East Chicago, Ind.

"Gas Analysis Applied to Blast Furnaces," by J. F. Triolo, Application Engineer, Iron & Steel Industry Div., Bailey Meter Co., Bala-Cynwyd, Pa.

"Computers in Fuel and Utilities Dispatching," by Lee I. Dickinson, Fuel Engineer, Lackawanna Plant, Bethlehem Steel Co., Lackawanna, N. Y.

"Modern Blast Furnace Blowing and Gas Recovery Systems," by C. W. Dunn, Superintendent Utilities, Fairless Works, United States Steel Corp., Fairless Hills, Pa.

2:00 pm—BLAST FURNACE SESSION—
Urban Room

Chairmen: C. A. Roberts, Jr., Chief Engineer, Phoenix Steel Corp., Phoenixville, Pa.

Stephen Vajda, Process Development Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

"The Injection of Auxiliary Fuel into the Blast Furnace," by Dr. Julien Raick, Consulting Engineer, Brussels, Belgium

"Natural Gas Injection at Great Lakes Steel Blast Furnaces," by William H. Collison, Plant Superintendent, Blast Furnaces and Coke Works, Great Lakes Steel Corp., Div. of National Steel Corp., Ecorse, Mich.

"Sintering Fans—Selection and Design Considerations," by Gerald J. Durning, Chief Engineer, The Green Fuel Economizer Co., Inc., Beacon, N. Y.

2:00 pm—ROLLING MILLS SESSION—
Monongahela Room

Chairmen: F. G. Kredel, Chairman Bar Mill Committee, Republic Steel Corp., Cleveland, Ohio

R. P. Schuler, Superintendent, North Mills, Inland Steel Co., East Chicago, Ind.

"Technological Exploitation of the Stretch-Reducing Process," by Dieter Hancke, Vice President—Sales, and Robert Hartenstein, Vice President—Engineering, Mannesmann-Meer, Inc., Youngstown, Ohio

"Design and Performance of Recent Developments in Bar Mill Cooling Beds," by Wm. K. Stamets, Jr., President & General Manager, Northeast Ohio Machine Builders, Inc., Columbiana, Ohio, and J. Ralph Dye, Works Manager, Milton Steel Div., Merritt-Chapman & Scott Corp., Milton, Pa.

"Pass Reduction Schedule for Optimum Production from Hot Strip Mill," by Dr. Betzalel Avitzur, Research Engineer, Applied Science Dept., Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

WEDNESDAY, SEPTEMBER 27

9:00 am—ELECTRICAL SESSION—
Urban Room

Chairmen: H. W. Dorset, Assistant Superintendent, Electrical Dept., Bethlehem Steel Co., Sparrows Point, Md.

John A. Drgon, Division Superintendent—Maintenance and Utilities, Edgar Thomson Works, United States Steel Corp., Braddock, Pa.

"Motor Heating Effects of Reactor Type Control Systems for A-C Cranes," by J. A. Halvorson, Electrical Engineer, Bridge & Crane Control Section, Cutler-Hammer, Inc., Milwaukee, Wis.

"Something Different in Reactor Crane Control," by C. A. Schurr, Supervisor of Systems Development Section, EC&M Div., Square D Co., Cleveland, Ohio

"The Crane of the Future," by F. M. Blum, General Sales Manager, Industrial Div., Harnischfeger Corp., Milwaukee, Wis.

"The A-C Mill Motor—A New AISE Standard," by Malcolm B. Antrim, Chairman, AISE Mill Motor Committee, and Manager, Engineering and Construction Div., Lukens Steel Co., Coatesville, Pa.

9:00 am—COMBUSTION SESSION—
Monongahela Room

Chairmen: William M. Bloom, Chief Fuel Engineer, General Engineering, Allegheny Ludlum Steel Corp., Pittsburgh, Pa.

A. S. Merrow, Assistant Fuel Engineer, Bethlehem Steel Co., Lackawanna, N. Y.

"Nitrogen from an Air-Separation Plant as a Heat-Treating Atmosphere," by B. Herbert, Metallurgist, and J. R. Rink, Research Metallurgist, Research & Development Dept., Inland Steel Co., East Chicago, Ind., and L. R. Chrzan, Laboratory Div. Head, and M. F. Hoffman, Project Engineer, Development Laboratory, Linde Co., Newark, N. J.

"The New 5-Zone Slab Heating Furnace at Campbell Works, The Youngstown Sheet and Tube Co.," by D. C. Haney, Superintendent, Fuel and Power, Youngstown District, and J. B. Mitchell, Assistant Superintendent, 79-In. Hot Strip Mill, Campbell Works, The Youngstown Sheet and Tube Co., Youngstown, Ohio

"New Pits at Acme-Newport Steel Co.," by R. R. Kuhni, Combustion Engineer, Acme-Newport Steel Co., Newport, Ky.

2:00 pm—MECHANICAL SESSION—
Urban Room

Chairmen: L. A. Fugassi, Chief Engineer, Midwest Steel Co., Div. of National Steel Corp., Valparaiso, Ind.

S. W. Stouffer, Director of Construction and Maintenance, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

"Welding—A Versatile and Economical Tool in Steel Mill Maintenance," by J. J. Matusek, Assistant Superintendent, Mechanical Dept., Inland Steel Co., East Chicago, Ind.

"Steel Mill Service Water Studies," by R. H. Anderson, Head, Cleveland Dept., Stanley Engineering Co., Cleveland, Ohio, and K. A. Roddy, Report Group, Stanley Engineering Co., Muscatine, Iowa

"Design Considerations for Belt-Conveyor Systems," by H. Colijn, Senior Technologist, Electromechanical Research, Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

2:00 pm—OPERATING PRACTICE SESSION—
Monongahela Room

Chairmen: Frank F. Argust, Superintendent, Industrial Engineering, The Colorado Fuel and Iron Corp., Pueblo, Colo.

H. F. Miller, Assistant General Manager, Bethlehem Steel Co., Bethlehem, Pa.

"Capital Investment and Productivity Measurement," by Wm. T. Hogan, S.J., Professor of Economics and Director, Industrial Economics Program, Fordham University, New York, N. Y.

"The Changing Open Hearth," by Edgar B. Speer, Administrative Vice President, Central Operations—Steel, United States Steel Corp., Pittsburgh, Pa.

"Noise Control in the Steel Industry," by James H. Botsford, Noise Control Engineer, Bethlehem Steel Co., Bethlehem, Pa.

7:30 pm—FORMAL DINNER—Ball Rooms

10:00 pm—DANCE—Urban Room

AISE members and guests. No admission charge.

THURSDAY, SEPTEMBER 28

8:30 am—INSPECTION TRIP—

Armco Steel Corp., Butler, Pa. Buses leave from Penn-Sheraton Hotel. Buses will be back to the Hotel at approximately 1:30 pm.

LADIES PROGRAM

Ladies Headquarters and Registration—
Hotel Penn-Sheraton
Parlors E & F

Monday, September 25

9:00 am.....Registration, Parlors E & F
9:30–11:00 am.....Welcome—Coffee

Tuesday, September 26

3:00 pm.....Fashion Show (Saks Fifth Avenue)
Terrace Room
Hotel Penn-Sheraton
4:00–5:00 pm.....Cocktails

Wednesday, September 27

11:00 am–2:30 pm....Brunch at the LeMont
Buses will leave Hotel Penn-Sheraton at 10:30 am
7:30 pm.....Formal Dinner—17th Floor
Ball Rooms
Hotel Penn-Sheraton
10:00 pm.....Dance—Urban Room

Honorary Chairwoman: Mrs. C. E. Pritchard
General Chairwoman: Mrs. J. H. Bray
Co-Chairwoman: Mrs. W. J. Wenger

To partially cover costs, a flat registration charge of $5.00 will be made which will cover all ladies activities except the formal dinner on Wednesday evening. This must be paid on registering, when tickets will be issued for these events.

Hotel Reservation

Make your room reservation directly to the Penn-Sheraton Hotel, giving time of arrival, length of stay and type of accommodations desired. Reservations should state that they are for the AISE Convention. If the hotel is unable to take care of you, it will forward your request to the Pittsburgh Convention Bureau, who will place you elsewhere.

Pittsburgh's new Civic Arena features a retractable stainless steel dome.

New Concepts in Power-Control Rooms for steel mill drive systems

by V. E. VERHEYDEN, Design Engineer, Industry Control Dept., General Electric Co., Roanoke, Va.
and D. C. NELSON, Plant Electrical Engineer, Jones & Laughlin Steel Corp., Aliquippa, Pa.

. . . . . use of preassembled, prelested, unitized power and control equipment can make substantial reductions in both over-all and installation costs and installation time. This may add from 15 to 25 per cent to original equipment costs, but over-all net savings up to 15 per cent can be realized.

TODAY'S modern metal-rolling and processing equipments produce more tonnage of high-quality product, with greater efficiency, than ever before.

To accomplish this, the mechanical equipment has become more complex, and to a far greater extent, the electrical equipment has become more complex because of the demands for higher speeds, more exacting control of the process and greater reliability. With each succeeding year, the industry has seen the initial cost, and the cost and time to install the electrical equipment, increase faster than the cost of the mechanical equipment. In some instances, the total cost of the electrical equipment has approached, and even exceeded, the total cost of the mechanical equipment.

As Jones & Laughlin Steel Corp. analyzed this situation, it became apparent that, in addition to higher labor costs, considerably more time was required at installation. More time was required to set in place, hook up, check out and tune up because of the increase in complexity and the number of pieces involved in the electrical system. It was recognized that the conditions at a construction site are far from the ideal for assembling and wiring all of the equipments to complete the electrical system. It seemed logical that considerable cost and time saving would result if more of this assembling and wiring were done in the factory of the electrical equipment supplier. The electrical equipment factory is equipped with tailor-made tools, jigs, fixtures, work stations, etc., and their design and use is planned by specialists in this field.

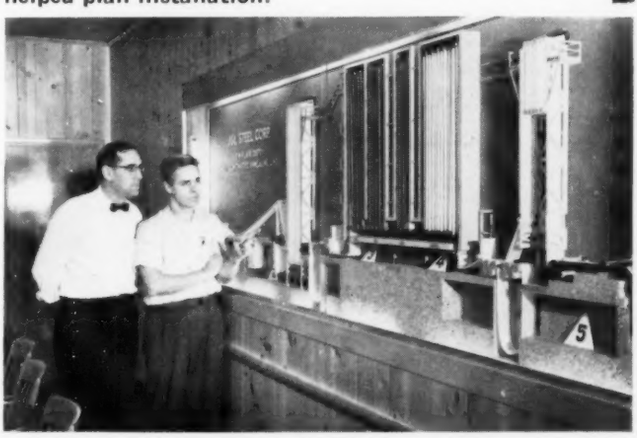
Early in 1957 a study was made to consider a more complete packaging of the electrical equipment. Several concepts and ideas were studied, such as:

1. A walk-in room vs a nonwalk-in room.
2. A totally enclosed room vs an open room.
3. A dead front panel vs a nondead front panel.
4. A-c control included or separate.
5. A control above the motor-generator sets or vice versa.
6. Motor-generator sets in the room or separate (open or enclosed).
7. Motor-generator sets on the mill floor with the control mounted below or above.

In any of these designs, the equipment would be supplied with self-supporting bases, ventilation, lighting and complete wiring and testing.

As these concepts were developed and evaluated, it was evident that the basic design could be very flexible, thus making it practical to custom build these equip-

Figure 1 — A model of the continuous annealing line helped plan installation. ■



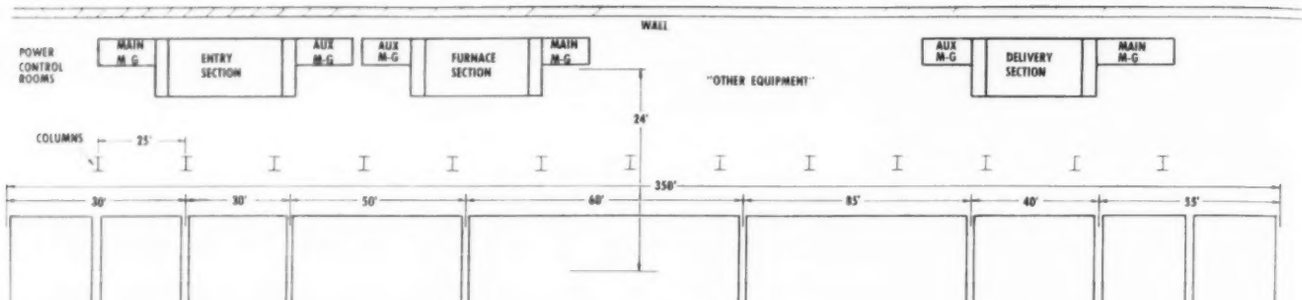


Figure 2 — The line control rooms were placed in relation to the line sections they control.

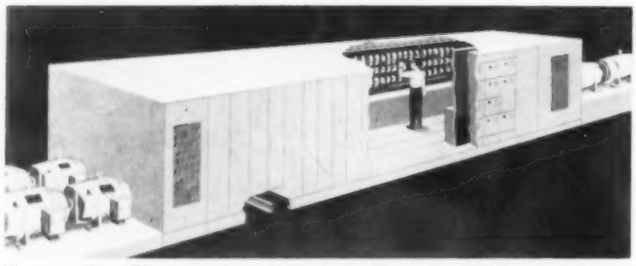


Figure 3 — The section drawing illustrates the unit type assembly utilized in the power-control room concept.

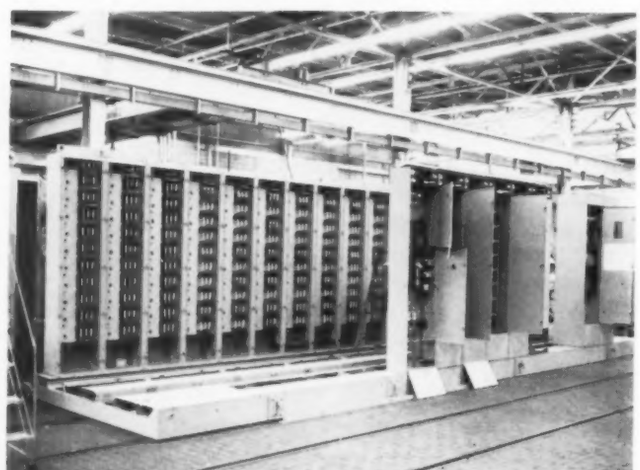


Figure 4 — The a-c control enclosures form the outside walls of the control room.

Figure 5 — The d-c controls are grouped on each side of the center aisle.

ments to satisfy any specific job application or conditions. In the steel industry, this is essential because each such control room must be system engineered and built to insure the best over-all design for the specific job.

ANNEALING LINE APPROACH

After evaluating these concepts, and how best to apply them to this specific installation, the following approach was taken:

Basic arrangements—Figure 1 is a scale model of the line equipment for this line. To get the proper perspective, Figure 2 shows the location of the control rooms in relation to the line equipment. The rooms were sectionalized so they could be located as near as possible to the section of the line being controlled. Figure 3 is a sectionalized unit consisting of the control room, the main and auxiliary motor-generator sets and the ventilating equipment.

Equipment included in the control room—In general, the control room includes the a-c group control, d-c adjustable-voltage and constant-potential control, low voltage rectifier control, motor-operated rheostats, resistors, etc., all integrally wired and tested together in the electrical equipment supplier's factory.

Construction and arrangement details—Standard a-c group control forms the outside walls of the room, see Figure 4. Under some conditions, the d-c control may form a portion of the outside wall if there is considerably more linear feet of d-c control than of a-c control. Inside the well-lighted room, the d-c control forms the inside walls on each side of the center aisle, see Figure 5. Here the power (armature loop) components are on the left, thus separating them from the relaying and regulating components which are on the right. The "regulator packages" with all rheostat adjustments and instrumentation are accessible and conveniently grouped together. All components are functionally and conveniently arranged to maintain the proper balance between compactness and accessibility. As on conventional equipment, heavy-duty components are used. This control room concept would not have been possible without these unit-mounted, front-mounted and front-wired components. However, if the use of considerably more space can be tolerated, back-wired components can be used, while retaining many of the advantages of the basic concept. The use of steel, for all control panel bases, greatly reduces the possibility of shipping damage and also reduces the over-all weight. At the end of the aisle is a motor-operated rheostat.

Outgoing connections are terminated in an enclosed compartment (Figure 6) at the bottom of each panel on both sides of the aisle. Wire and cables from the equipment at the line, enter either through conduit plates or an open bottom, from open trays or conduit under the floor.

All a-c and d-c wire and cable connections between the control, the motor-generator sets and the ventilating equipment are factory installed in wireways in the base of the room's structure (Figure 4). Easily removable plates are provided for access to this wire and cable. A network of wiring channels is provided to facilitate tracing, changing or adding wires during installation tune up. At each shipping split, all wires are terminated in push-on connectors and cables are terminated on screw-type terminal boards. This aids tremendously in the reconnecting of the equipment in the field.

Small control resistors are mounted inside the regulator packages. Larger field and control resistors are mounted immediately under the room's ceiling (Figure 7) along with control-power and generator buses and light fixtures. The buses are insulated to protect maintenance personnel. Power, dynamic braking and line dropping resistors are mounted outside on the top of the room, see Figure 8. The protective covers are removed in the figure.

Separate enclosures which form plenum chambers contain fans, filters, louvers, etc. Automatic, renewable or throw-away filters can be provided along with a manometer to indicate when the filters have become dirty. A clean supply of air is available to cool the rotating machines and to keep the control room under a slight positive pressure. A separate fan (Figure 9) supplies air to each motor-generator set and to the control room.

The motor-generator sets are readily accessible since they are located outside of the room. They are of the enclosed, separately ventilated type (Figure 10) with a completely self-supporting base. They are factory alined, connected to the control and tested. Although the alinement needs to be checked at installation, very little time is required because of the complete alinement done in the factory and the effectiveness of the self-supporting bases. Air is supplied to the motor-generator sets through their base. A cableway is provided, along the conduit-box side of the set, for installing wire and cable between the control room and the machine terminals. Where applicable, either tube or metallic-type rectifiers can be supplied, in place of motor-generator sets, for the power conversion.

SAVINGS

Since this is the first continuous annealing line installed by J&L, an accurate, detailed analysis of cost savings could not be made between this and a conventional installation. Depending upon specific conditions, the cost of installing conventional electrical equipment may be as much as 40 to 100 per cent of the original cost of the electrical equipment. It would be impossible to make an absolute comparison because of the many variables: location and arrangement of mechanical equipment, control equipment and rotating machines; motor or control rooms or basements; conduits or trays; amount of material; labor rates; etc.

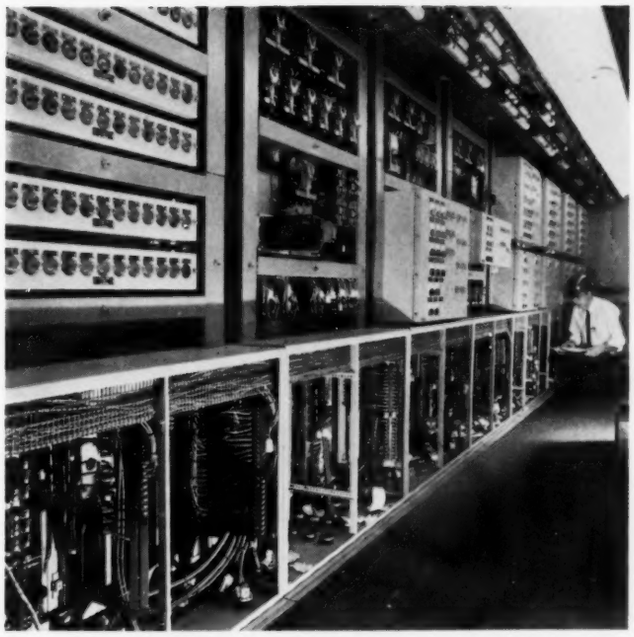
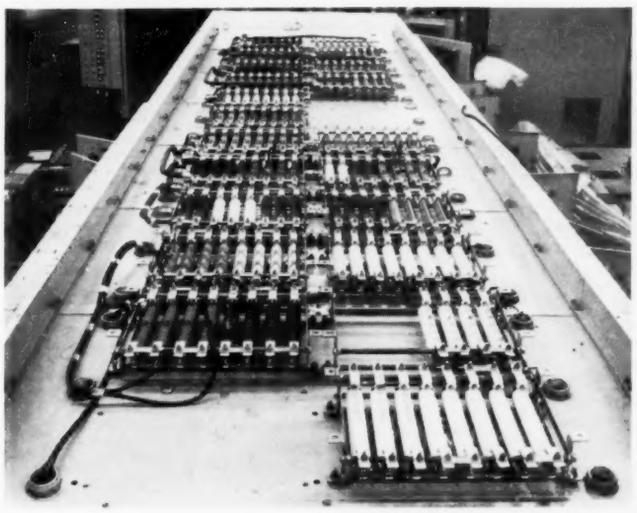


Figure 6 — All terminal connections are located in compartments underneath each d-c control section.

Figure 7 — Insulated buses and large wire-wound resistors are located close to the ceiling.

Figure 8 — Dropping and dynamic braking resistors are mounted on the roof of the control room.



On the basis of past experience, and the data available from this installation, it can now be said that it is possible to reduce individual installation costs up to 50 per cent by utilizing this control room concept. These savings in time, labor and materials are realized by reductions in:

1. *Installation engineering expense*—Time and number of drawings.

2. *Excavation, foundations and concrete work*—Control rooms and motor-generator sets were supplied with self-supporting bases.

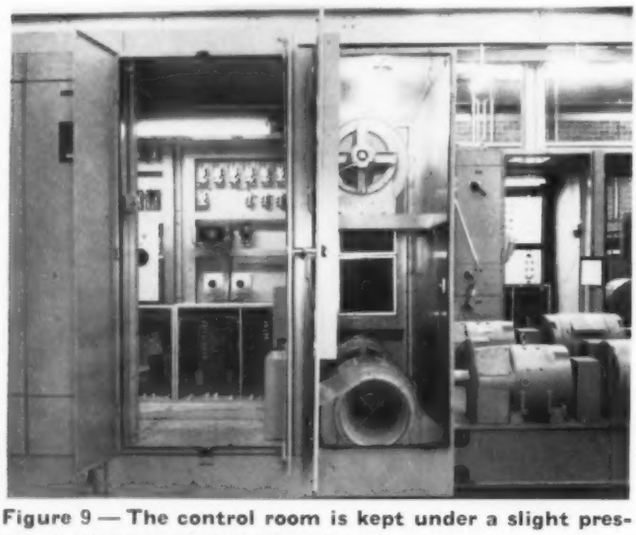
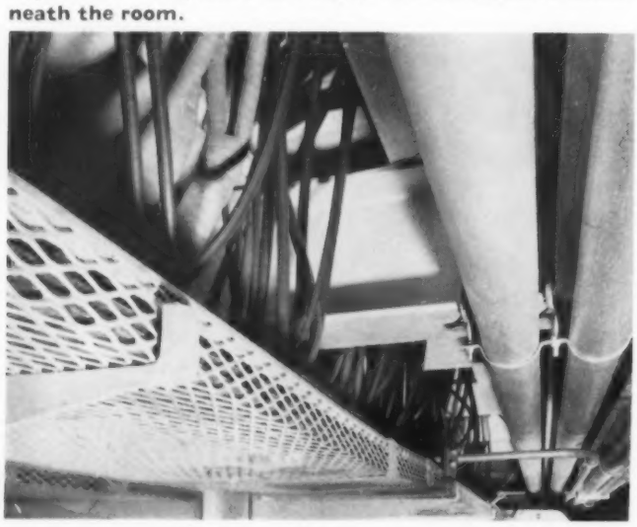


Figure 9 — The control room is kept under a slight pressure to decrease dust infiltration.

Figure 10 — The motor-generator sets are force cooled by air supplied through ducts in their base.

Figure 11 — Only one cable tray per side is required underneath the room.



3. *Conduit, wire and cable*—Connections between the a-c and d-c control, ventilating equipment and motor-generator sets were factory installed. The remaining conduits, wire and cable, between the control and the line electrical equipment, were reduced in length because the control was nearer the line equipment. This is demonstrated in Figure 11, which shows the one cable tray under each side of the room.

4. *Ventilation for electrical equipment*—Ventilating equipment was supplied as part of the power-control rooms.

5. *Separate control houses or motor rooms*—Associated engineering, materials and construction expense were eliminated.

6. *Rigging and lining-up of electrical equipments*—Control rooms and motor-generator sets were supplied with self-supporting bases. There were fewer pieces of electrical equipment to be identified, handled and set in place. For example, considering only the motor-generator sets, a-c control center, d-c control panels and motor-operated rheostats, 11 pieces were supplied for this line where 33 pieces of conventional equipment would have been involved.

7. *Hook-up and check-out time*—Fewer connections to make.

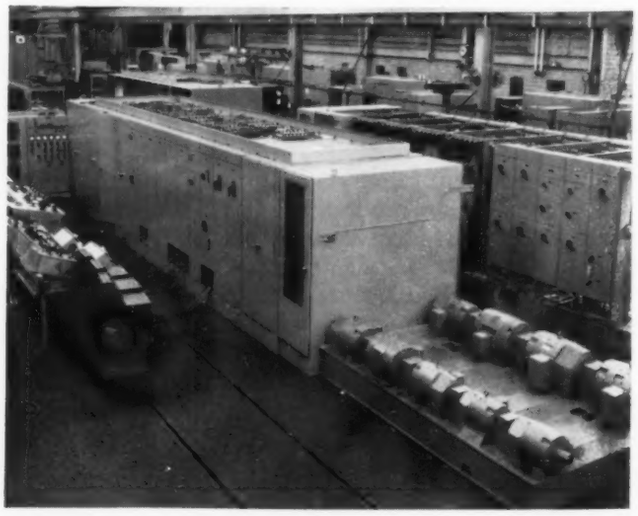
8. *Tune-up time*—More complete factory testing, see Figure 12. Rotating machines were connected and regulators tuned in the factory. All sequence and operating tests were performed using the actual operator's devices.

Many of these items contributed to reducing the over-all installation time. This made possible an earlier startup which could represent a considerable sum of money in new or increased business. On this line, for example, the rated output of annealed strip is 30 tons per hr or 720 tons per day.

Depending upon the conditions on a specific installation, there may be other areas where savings can be realized. Because of better space utilization, floor space is saved, or it may be possible to better utilize space between building columns, see Figure 13.

Although it would be difficult to attach a dollar savings, valuable construction engineering time could be gained earlier in the job cycle by designing a centralized conduit entrance into the control room. This

Figure 12 — All the equipment was tested and adjusted at the factory.



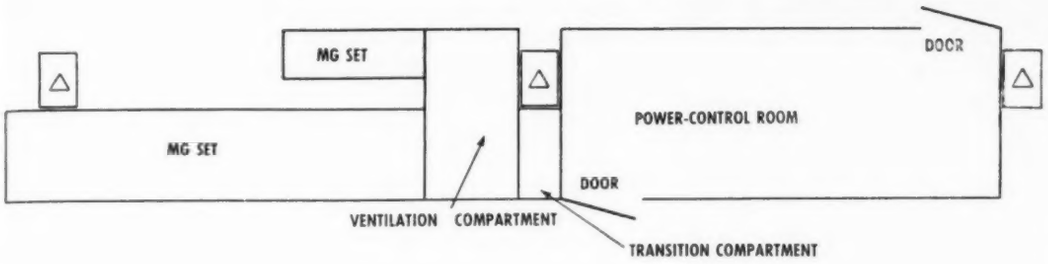


Figure 13 — Utilization of floor space areas which are normally unsuitable is a flexibility factor.

would make it possible to complete conduit and foundation drawings long before exact wire termination points were known.

APPLICATION

The actual application of the basic concept is unlimited. From a power-level standpoint, there may be some types of drives where there are practical limitations as to the electrical equipment included. For example, it may not be economically feasible to include 4000 to 10,000-amp circuit breakers, and their associated bus, in a control room. However, when the power conversion equipments are located in separate rooms, this construction is ideally suited for housing the control, regulator and excitation equipment, and many of the advantages of the basic concept are still retained.

The most practical applications are those where the user receives the greatest benefits:

1. Every kind of processing line is particularly adaptable to the use of these control rooms. These lines require a relatively large amount of control equipment and may require many separate units of power conversion equipment. The type of control components, and the power level of the conversion equipment involved, make them ideally suited for this type of construction. Many of the lines are several hundred ft long. Much can be saved by placing several of these control rooms at the proper points adjacent to the line.

2. Small rolling mills, up to approximately 500 hp, are adaptable to control rooms for reasons similar to those described previously.

3. Large rolling mills, except for the main motor-generator sets and main circuit breaker panels, are adaptable to the use of these unitized control rooms. As static devices can be more widely used, an even larger share of the electrical equipment, for these mills, can be included as part of the control room.

4. Some auxiliary drives, particularly adjustable voltage drives, lend themselves to this construction. It may be feasible for those auxiliary drives, such as coilers, runout tables, etc., which are remote from the main mill. It would be equally feasible to use these control rooms for the auxiliary drive electrical equipment where there is no motor room, or there is no space available in the motor room.

5. For revamps or additions to existing lines or mills, this control room concept may also be applicable if the existing control house or motor room will not physically house the additional equipment. Because it is a complete assembly, this control room can go anywhere. It can be fitted into any space that is available because of the flexibility of the design.

ELECTRICAL EQUIPMENT COSTS

To determine the over-all savings to the user, the additional original cost of the electrical equipment must be deducted from the savings realized in installation costs. Supplying unitized control rooms, rather than conventional equipment, adds 15 to 25 per cent to the original cost of the electrical equipment, such as motors, motor-generator sets and control. For a specific job, the actual increase in electrical equipment cost depends upon its complexity, magnitude, and type of line or mill involved.

Considering the additional equipment costs and the savings in installation costs, the possible net savings can be as much as 15 per cent on the over-all installed cost of the electrical equipment.

SUMMARY

This first attempt, on a continuous annealing line, proved that individual installation costs can be reduced up to 50 per cent by utilizing this control room concept. It is logical to expect comparable savings on other applications and installations. As more experience is gained and further refinements are made, in this basic concept, further reductions in installation costs and time should be realized.

Discussion

PRESENTED BY

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A. Ketvirtis: Experience dictates that in order to reduce the mill downtime and achieve smooth, continuous operation, the following basic engineering

principles must be observed:

1. Over-all planning of the space allocation for equipment to facilitate maintenance.
2. Standardization of equipment and its basic arrangements.
3. Allowance for future expansion.
4. Minimizing fire hazard.

With careful planning, there should be no particular necessity to crowd one class of equipment in a space which will make maintenance difficult.

The concept presented in this paper is justified only under very specific circumstances where space is extremely important. Under normal conditions, proper housing of expensive electrical equipment should not be a problem.

The compact, prewired control room, as it is proposed in this paper, is an extension of the manufacturers' ideas into the mill layout and engineering field. As a result of this extension, the control room becomes a piece of equipment. The reduction of installation costs is in fact the transfer of part of the cost to the manufacturer's shop.

It is good practice that the space for access to the equipment components, particularly cable terminals, should be so arranged that quick checking of circuits is possible. It is also important to separate different circuit systems in separate raceways. From the cable tray arrangement shown in this method, it is difficult to understand how this arrangement can meet the fire hazard requirements and rules governing electrical equipment installation.

In the process of planning a new plant, the periods allocated for design, building construction, manufacturing of equipment and its actual installation in the field overlap. The order for equipment must be placed before the final design of the system is completed. If equipment components and arrangement are such that additions and deletions are easy to make, then the manufacturing of control equipment can begin as soon as major parts of the motor controls are known. In the packaged arrangement, the size of the over-all unit depends on the amount of the control equipment required; therefore, the construction of the package unit can start only when complete design of the electrical system is finished. This condition may require more time for design, and will result in a longer engineering and construction period.

It would be interesting to know the comparative cost of equipment arranged in a conventional manner vs the arrangement suggested in this article.

Member: What would happen in the event of bombing, that is destruction by a bomb of the control equipment? Also, what is used in connection with electric precipitators? Is there any particular design for that?

V. E. Verheyden: The subject is control rooms for drive systems not compact packaged drives. This control room contains heavy-duty, mill-type control and power conversion equipment for the complete system.

Devices are not crowded because the spacing and arrangement is basically the same as a conventional open, self-supporting type panels. The aisle is 3½ ft wide between the terminal board compartments. For this line a large number of spare starters plus spare spaces were provided in the a-c control center portion, i.e., in the "furnace section room," three complete vertical sections of control center were provided plus other individual spare starters and spaces. In the d-c control, five to 10 per cent spare components (relays, rheostats, capacitors, etc.) were provided. There were also blank spaces, plus some blank complete panels, provided for changes or further additions. This should suffice unless a complete revamping is made to the line. In this case, a new section could be built and, by moving one motor-generator set, added to the control room. One of the advantages of this concept is that a complete new unit can be built and placed wherever space can be found.

As far as fire hazard is concerned, J&L felt that fire protection was not needed for this installation. Fire protection can be supplied if it is required on a particular installation.

There is no reason why a "user" cannot maintain this equipment without relying more on the "supplier." This electrical equipment is the same as for any conventional control. The user can rely on his regular personnel who normally maintain this type of electrical equipment.

It is true that a major portion of the details on both the a-c and the d-c control must be settled before the size of the over-all units can be determined. However, the reduction, by weeks, in the installation time can allow time to more completely engineer the system in the earlier phases of the job.

As far as protection against catastrophe or bombing is concerned, the situation would be the same with these control rooms as with conventional equipment in a motor or control room. There are no emergency power supplies. The basic power source is the main incoming a-c circuit which supplies power to drive the motor-generator sets.

No electric precipitators were used. In the J&L installation, renewable type filters were used in the ventilation compartment. The use of continuous roll-type filters and electric precipitators was investigated. Depending upon the needs of any specific installation, either of these could be made a part of the ventilation equipment.

D. C. Nelson: Portable fire equipment is located next to the package units, and it was not felt that it was necessary to increase the original cost by having special fire extinguishing equipment installed.

H. W. Dorset: Were there any real problems on startup of the operation?

D. C. Nelson: On tune up of the new equipment, the alinement of all rotating equipment was checked. Only a small misalinement on one of the motor-generator sets was found. Tune up of the control saves time. By having the control and rotating equipment in a package unit, it can practically be plugged in. The wiring and cable can be run from the motors to the place where the package is to be set down, and it is only a matter of connecting the terminals until final check out can be started.

In the electrical installation of a process line or mill, this concept permits the start of the check out without waiting until all the other crafts have completed their work.

H. W. Dorset: The author stated that savings up to 50 per cent of installation cost could be realized, and he also said that there is no previous continuous an-

nealing line with which to compare this. There was no statement made as to whether J&L installed it with their own force or contracted it. Because it is new and because there was no previous experience, how would one persuade a contractor that it was only going to cost him 50 per cent as much to install this job as it might cost him with the conventional type of control?

D. C. Nelson: The installation was done with our own forces, and the estimated savings were arrived at by using the number of hours and a contractor's price per hour and comparing this figure with the cost of similar jobs put in on a conventional basis. As for obtaining bids on new jobs and getting a contractor to admit that this method would cost him 50 per cent less to install than the conventional method, that is another matter. One would have to evaluate the drawings and design that were put out for bid, which should show the difference in time and material required to do the job. It could be done, and undoubtedly, a cheaper quotation would result.

V. E. Verheyden: As mentioned earlier, J&L did not have another comparable, conventional installation. This was their first continuous annealing line. Of course, they had costs on other types of lines and mills which gave them enough facts to approximate their actual savings on a percentage basis.

R. O. Gee: E. E. Vonada presented a paper in Pittsburgh before the AISE in September, 1957 entitled, "Electrical Advances Can Reduce Installed Costs" (1958 AISE Proceedings, p. 782).

In part he said, "The packaged drive idea is being extended to include motor-generator sets and control for larger horsepowers and for combining multiple motor-generator sets and control panels into a single prefabricated steel building or leanto. Lighting and ventilation provisions are made as part of the fabrication. For the leanto type construction, motor-generator sets and control are all assembled and factory wired in the building and shipment is made as a complete package. Where separate buildings are required, the motor-generator sets and control are designed to facilitate easy assembly and interwiring in the field."

Packaged drive installations can usually be made at lower installed costs than separate control and motor-generator set installations.

In 1937, the first packaged, variable-voltage drive system was introduced. Until that time, the use of variable-voltage d-c power had been restricted almost completely to heavy industry. Mass produced packaged drives brought the advantages of variable-voltage control to light industry. In the next 20 years the packaged drive found its way into every industry where adjustable-speed, increased productivity, more exacting product quality control, etc., were required.

In most processing line installations, the length of line can make a very expensive electrical installation when one central power and control room is provided. Mounting the control and power conversion equipment for a given section adjacent to that section reduces the initial cost of installation and localizes the trouble-shooting and maintenance operations. The concept, if properly utilized, can result in reduced initial capital investment, insofar as the installation is concerned, of up to 50 per cent.

A-c distribution appears generally less expensive and more efficient than variable-voltage d-c distribution. Hence, sectionalizing and utilizing a-c load centers, and fuller localized d-c power and control rooms also leads to economy.

The utilization of a-c plant distribution and conversion to variable-voltage d-c at the point of use simplifies control systems. The packaged drive has found tremendous acceptance in most industries, in a multitude of applications, and has provided decreased initial capital expense, decreased installation costs, savings in costly plant floor space, and less weight support.

There are several successful installations of packaged power, control and machines in the wire drawing industry. Not only is the power and control equipment packaged, but the package is incorporated within the wire drawing machine itself to provide a totally-packaged ventilated, lighted, preassembled and pretested wire drawing machine and drive that has been started up in its entirety prior to its installation in the user's plant.

There will be some installations where only the control portion lends itself to the control room package. A recent installation of this type was made in a paper mill and a separate steel, air-conditioned, lighted control room with entrance and exit doors at each end of the room provided all control and regulating equipment to the mill prewired to entrance and exit terminations in a self-supporting steel room.

There will be installations where, although sectionalized (as on a long processing line), the line drive equipment can include the packaged room enclosure for the control portion only, with the motor-generator sets mounted on a common base, being preassembled, prewired and pretested.

Much of the electrical industry's research and development dollar is being devoted to a development of methods, techniques and equipment which will permit production of power and control processing line equipment with higher productivity, increased quality control, greater flexibility and fewer components. The packaged power and control room and a packaged drive are examples of this technological advancement.

Industry today is finding it necessary and desirable, in order to provide a profitable and a growing operation, to place more and more of the control of a plant or mill's operation into the hands of its management. The packaged concept does place more control into the hands of management insofar as initial equipment costs, installation costs and maintenance costs are concerned.

V. E. Verheyden: There is one basic point which should be reiterated to avoid any misunderstandings. Control rooms for drive systems and not packaged drives are under discussion. This control room is system engineered and custom built to insure the best overall design for a specific installation. It utilizes the same heavy-duty, mill-type equipment as currently furnished for conventional installations. This equipment ranges from rotating to static conversion equipment; from 2500-amp contactors to transistorized rate reference circuits; from a-c motor starters to the motors they start; and everything between. These components insure reliability. Accessibility is designed in to insure ease of installation and maintenance. This concept is not to be confused with compact, general duty, standardized packaged drives. ▲

AUTOMATION

MOST people when thinking of automation will think of a machine that operates unattended, taking the raw material in at one end and delivering the finished product at the other.

That is essentially what is done in the seamless tube mill at Mannesmann Tube Co., Ltd., and what could be called a normal operation. However, under fault conditions an operator must still be able to assert control over the equipment.

The automation may detect some of the predictable fault conditions and interrupt the flow of material, but the majority of faults that occur to interrupt normal operation are of such a nature as to require clearing by hand by operating personnel. These are such things as removal of stickers and cobbles, mill tool changes, and mill setup and adjustment requirements.

However, by designing the electrical circuitry in coordination with the mechanical equipment and the process requirements, it is advantageous to operate the mills automatically under normal conditions, and depend on the operators to interrupt the automatic cycles under abnormal fault conditions and clear the faults.

One of the definite advantages in operating automatically is the sustained and consistent high rate of material flow, independent of operator fatigue and error.

A second significant advantage of automation in a plant is that it introduces duplication of control circuits to some extent. Appreciating that manual operation is an off-normal condition, it is possible to eliminate most of the interlocking in the manual circuits. By minimizing the interlocking of the manual circuits, the operator may frequently continue production using the manual controls in event of failure of the automatic circuits. Each operator has the manual controls at his fingertips and may at his option switch to manual.

The automatic cycle of the No. 2 piercer is described as being typical of the automation at this plant.

Most of the automatic actions in the hot mill section of the mill are initiated by a modified radiation detection device that has its maximum sensitivity to infrared radiation. It consists of a lead sulphide cell that is technically called a semi-conductor, and has the property of decreasing electrical resistance when exposed to infrared radiation. This device is used extensively as a flame detector, and its successful operation is based on the fact that radiation from any flame is constantly fluctuating. The flame fluctuations are most pronounced at ten cycles per sec. In the application of this device radiation is picked up from a hot body emitting infrared radiation at a steady rate. A circular, perforated disk is driven in front of the cell to produce a radiation fluctuation of ten cycles per sec to simulate flame conditions.

Moreover, this device is very dependable. Originally in the more critical applications there were two of these units in parallel to provide signal duplication in event of failure of one of the units. This has proven to be unnecessary.

The thrustblock movements are controlled by inductive limit switches. These inductive limit switches consist of a number of turns of wire wound on a laminated u-shaped steel core. This coil is in series with a capacitor, and they are tuned for series resonance under normal conditions. A relay is connected across the capacitor to pickup when the circuit is tuned. The circuit is detuned and the relay drops out, when a steel plate mounted on the thrustblock carriage passes in front of the inductive limit switch.

There are six inductive limit switches mounted on the piercer thrustblock ways. These are the forward and reverse slow-down limit switches, the forward and reverse backup limit switches, and the forward and reverse stop limit switches.

As the thrustblock passes the slow-down limit switch, it calls for regenerative braking for deceleration. If the regenerative braking is not applied, or if it has not reached sufficient amplitude by the time the thrustblock passes the backup limit switch, dynamic braking will be applied to decelerate.

When the thrustblock decelerates in the forward direction it advances the bar into the mill at a creep speed to pick up the point. As the thrustblock approaches the stop position, a current limit circuit is applied that will hold the thrustblock against the forward stop until latched.

To consider an automatic cycle of the No. 2 piercer, consider a shell in the outlet trough of the No. 1 piercer, a shell in the alinement conveyor ahead of No. 2 piercer, a shell having passed through No. 2 piercer and the receiving trough between No. 2 piercer outlet and the plug mill clear to receive a shell.

As the No. 2 piercer load relay drops out, it starts and raises the pull-out rolls, unlatches the thrustblock, opens the inlet guide covers and clears the kickout from the inlet alinement conveyor to operate. The latch open starts the thrustblock reverse. As the thrustblock passes the reverse backup inductive limit switch, it picks up a timing relay that initiates the kickout of the shell to the plug mill. The kickout is also interlocked to a permissive radiation detector sighted ahead

IN A SEAMLESS TUBE MILL

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. . . . . proper automatic control requires dependable equipment plus the ability to impose manual override conditions at any time deemed necessary by the operator. . . . .

of the stripper block to ensure the shell has stripped back. This detector also stops and lowers the pull-out rolls. The purpose of the timing relay on the kickout is to permit initiating the kickout before the bar is clear of the shell. The reverse stop position of the bar is set so the bar leaves the shell at high speed.

After the shell is kicked out, the thrustblock starts forward, interlocked through a cam limit switch on the kickout drive, to ensure the kickout arms are clear for the bar to advance. This cam switch is actually set so the thrustblock starts forward before the kickout has stopped. A timer is in this circuit that can be switched in or out, and adjusted to determine the length of time the bar stays in the reverse position. With the timer switch on by-pass the thrustblock comes forward as soon as the kickout has operated.

As the load relay dropped out, the inlet guide covers opened, and the shell in the alinement conveyor kicked into the inlet trough. A radiation detector sighted at the stop on the alinement conveyor drops out, and operates the alinement conveyor trap door to its receiving position. This detector dropping out also clears the kickout from the No. 1 piercer outlet to operate. The shell from the No. 1 piercer rolls down the skids into the alinement conveyor trap door. The shell then picks up another infrared detector that actuates the trap door to its down position, placing the shell on the conveyor rolls of the alinement conveyor. Then it is advanced and alined against the fixed stop. A detector sighted at the inlet trough of No. 2 piercer will prevent kickout from the alinement conveyor if a shell is in No. 2 piercer inlet trough and the load relay has not yet picked up.

With a shell in the No. 2 piercer inlet trough, a detector will close the circuit to energize the pusher and close the inlet guide covers when the thrustblock is in position. There are two circuits that may be used to indicate the thrustblock in position. One is a limit switch that closes when the thrustblock latches. The other is an advanced signal that picks up from the thrustblock forward-backup inductive limit switch. This signal picks up a timing relay that is normally adjusted to energize the pusher from one half to one sec in advance of latching. The inherent inertia delay of the pusher permits the thrustblock to latch before the shell is pushed into the mill.

The pusher push time is adjustable by the operator, by means of an adjustable electronic timing relay at his control desk, which is normally set about one sec.

As the shell advances through No. 2 piercer, the bar steadiers are automatically opened by detectors, sighted about three ft ahead of each bar steadier.

When the No. 2 piercing mill operation is complete the load relay drops out and the automatic cycle repeats. ▲

The Use of Castables in repairing blast furnace linings

by A. EUGENE FREY, Practiceman,
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. . . . use of castable refractory in the patching of blast furnace throats and stacks permits speed and ease of repair. Use of isotopes can check condition of refractory during operation. . . .

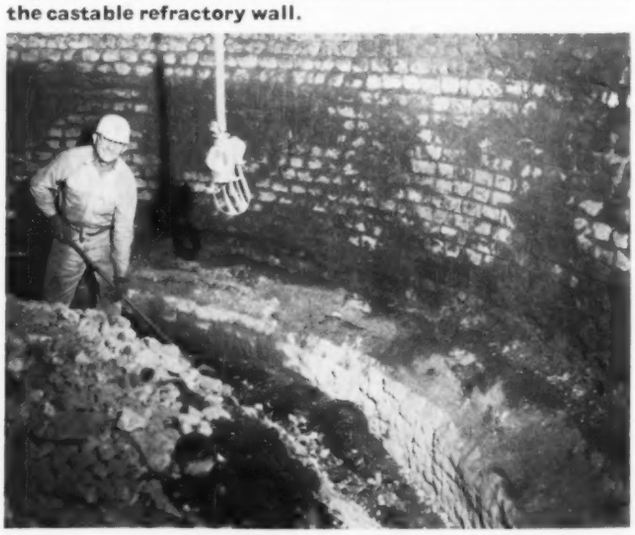
INSPECTION was made of the throat areas of the four blast furnaces at the Pueblo plant of the Colorado Fuel and Iron Corp. while the steel strike of 1959 was in progress. This inspection was accomplished by lowering cameras past the large bell into the top of each furnace and taking pictures by remote control, a technique pioneered in 1957. The photos showed that the wear plate area of F furnace had lost all its armor and the throat in D furnace had lost many of its wear plates, see Figure 1. As the strike continued and the furnaces cooled, supervisory personnel entered the tops of the furnaces through the bleeder inspection doors for a closer look at the throat sections. Throat patching was deemed necessary for these two furnaces before blowing them in from bank after the strike.

Castable refractory was chosen for the patching for several reasons. It would relieve part of the huge work load accumulating to the bricklayers as a result of the strike. The patching could be completed more quickly than by laying brick. The patching could be done by blast furnace labor under supervision from the refractory company. The castable should have a life comparable to that of firebrick.

Several refractory companies were contacted, and they agreed that such patching was practical. All but one of the companies wanted anchoring studs welded to

Figure 1 — Many of the wear plates in the throat area of D furnace were missing.

Figure 2 — Bricks were removed to provide a solid base for the castable refractory wall.



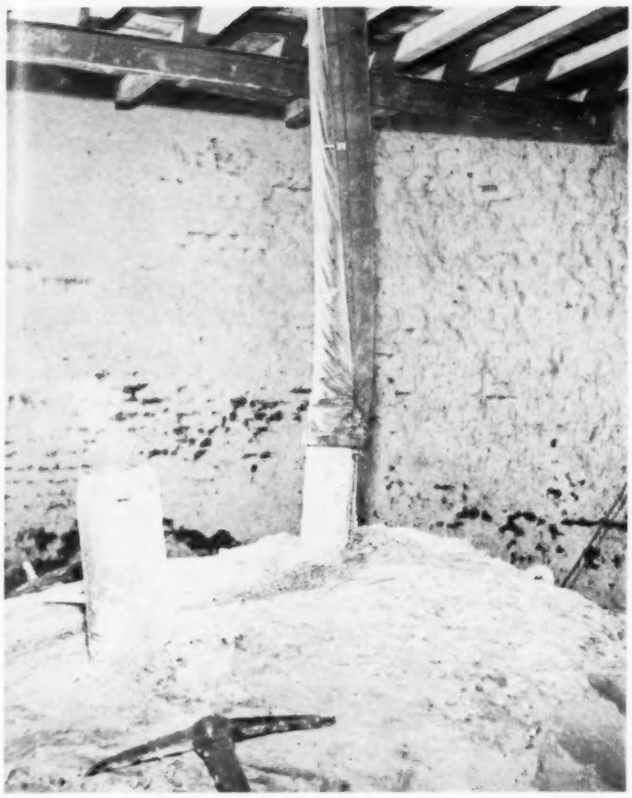


Figure 3 — Vent pipes were placed in the center of the burden, which was then covered with a layer of special concrete.

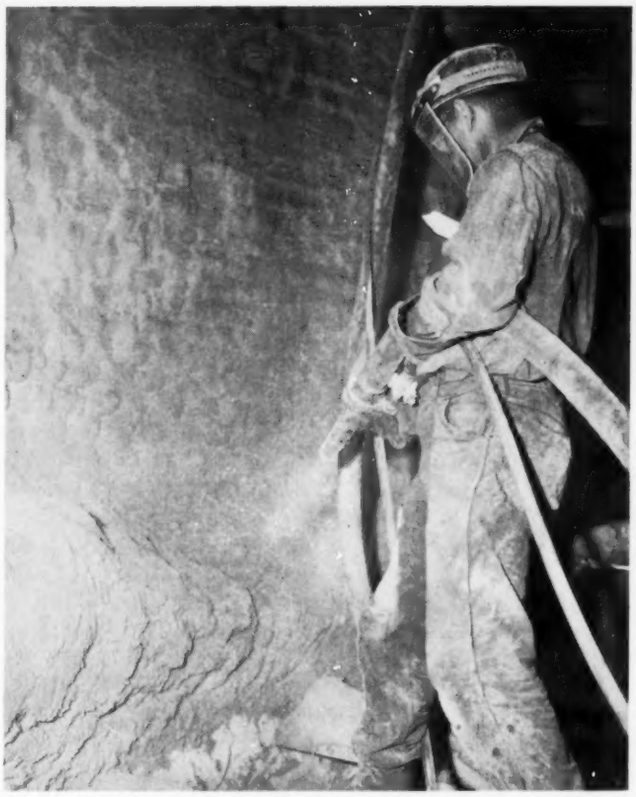


Figure 5 — The refractory was sprayed on in layers several in. high and 22 to 26 in. thick.

the shell, which would have required going through the one remaining row of brick. One refractory company thought that the unanchored castable would be satisfactory if a footing could be found on which to start building it. Probes through the banking burden indicated that there was a ledge of brick below the worn throat areas in both furnaces. Arrangements were made to have the castable material, two pneumatic placement guns and experienced operators available immediately at the end of the strike.

It was decided to patch F furnace first because it is the largest furnace; it did not require any other repairs; and the burden was low enough in the furnace that it required little work to prepare for the patching. The strike ended November 7, 1959 and the next day crews were preparing F. It was not necessary to remove the top from the furnace. The large bell was opened for the materials hoses. The small amount of burden that had to be moved was shoveled to the center of the furnace, see Figure 2. A course or two of brick was taken from the top of the ledge to make sure the ledge was solid. Two 8-in. vent pipes were placed in the center of the burden, then a 6-in. layer of soft-setting special concrete was used to seal the top of the burden and to give a working floor, see Figure 3. The vent pipes were connected by flexible hoses to draft up the bleeders. A small blower provided fresh air in the furnace. An automatic gas alarm was used to provide protection against gas poisoning. The two placement machines were put up on the furnace top platform and air and water connections provided. The material was hoisted to the top of the furnace on pallets.

Figure 4 — Two, 2-compartment machines were used to spray the refractory.

The machines (Figure 4) were first used to clean the remaining brick by sand blasting. This type of machine has two compartments. The material is completely mixed with the full amount of water in one compartment and then forced out in slugs by intermittent pulses of air. In the second compartment the next batch is being prepared. Actual application of the castable started November 11, 1959. It was sprayed on in layers several in. high and of full thickness, which was 22 to 26 in., see Figure 5. Extremely cold weather hampered the spraying operation, but the patching was completed November 14. Total height of the patch was 16 ft. The weight of castable used was 143½ net tons including spillage and rebound. Radioisotopes were placed in the patch to help determine the life of the patch. The furnace was on wind November 15.

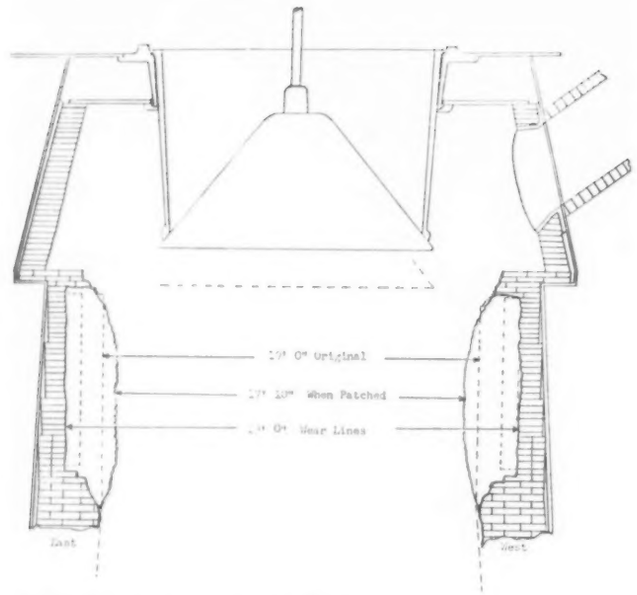


Figure 6 — Sketch of patch in D furnace.

Meanwhile mechanical crews had removed part of the top of D furnace which needed repairing. The big bell and hopper were left in the furnace but the bell was swung to one side. All the throat armor had been missing in F but only about one third was gone in D. It was originally planned to just patch the area of missing wear plate in D. However, in trying to shape up the loose ends of the remaining section of armor in D it was found that all of the remaining armor was loose. It was then decided to remove all the remaining wear plates in order to make a good patch. After this was done, and three carloads of burden taken out, the top was sealed off with the special concrete and a hanging scaffold installed. The pneumatic machines were taken from F and put on top of D on November 15. The brick were sand blasted that night. Application of the refractory started at 4:00 P.M., November 16, and was completed at 7:00 A.M., November 17 (15 hr). Figure 6 is a sketch of the patch in D. Total castable used in D was 104 net ton including spillage and rebound. Figure 7 shows the completed patch in D being sprayed with water. The spraying is necessary to keep down the heat developed during setting. The afternoon of November 17, the splash material and concrete seal were broken up with jackhammers. That night and the next day the top was put back on. The wind was on the furnace at 7:00 P.M., November 18. All four furnaces were casting $11\frac{1}{2}$ days after the end of the strike.

Figure 7 — The castable was sprayed with water since considerable heat is developed during the setting of the refractory.

At the E. and G. Brooke plant, it was necessary to replace the blast furnace hearth and bosh following the steel strike. During the cleanout the stack lining was found to be considerably eroded in the region of the in-wall cooling plates and also about 10 ft below the throat wear plates. As a result of the success in patching the Pueblo furnaces, plans were made for a complete stack patch. A hanging scaffold was built by bringing materials in through the tuyère cooler openings. The brick lining was cut back above the mantle to insure a good footing for the castable. A single gunning machine was brought onto the cast floor. A hose run up through a tuyère was used to place the castable. As shown in Figure 8, two types of refractory were used. The lower part of the furnace was covered with material having a maximum service temperature of 3000 F, while the upper part received the regular high strength refractory which has a maximum service temperature of 2500 F. Thickness of the patch varied from 4 to 18 in. The furnace lines were maintained by stretching piano wire from the wear plates to the top of the straight section above the mantle. A thin layer of castable was sprayed over the new brick in the hearth and bosh to protect them during blowing-in of the furnace. Total elapsed time for the patching of the furnace was 87 hr; actual machine time was 45 to 50 hr. Total refractory used was 173 tons of which 20 per cent was rebound and falloff. That is a much higher per cent rebound than occurred at Pueblo.

USE OF RADIOISOTOPES

As the end of the strike approached and the arrangements were completed for the castable refractory, blast furnace supervisors were trying to work out a method of determining the life of the patch. The suggestion was made that radioactive material be buried in the castable at various locations and checked at frequent intervals with a geiger counter to see if the castable was still in place at each location. It was decided to do this on F furnace if arrangements could be made quickly enough so as not to delay the patching of the furnace. Calls to several blast furnace equipment manufacturers indicated they had no experience in this field, however, one of them suggested getting in touch with a company who eventually contracted to help prepare an atomic energy license for CF&I, to supply the equipment, and to train and supervise personnel in the use and installation of equipment and radioisotopes.

The radioisotopes chosen were cobalt 60 wire sealed in stainless steel needles. Cobalt 60 is relatively cheap and there is no danger of leakage or contamination from the wire. It has a half life of 5.27 years which fits in well with the normal lining life of the furnace. Six locations were picked for the radioactive sources. Three are on a plane five ft below the opened large bell. Starting on the south side of the furnace they are spaced equidistant around the furnace and are approximately in the middle of the patch, see Figure 9. The other three isotopes are on a plane seven ft below the upper sources. These

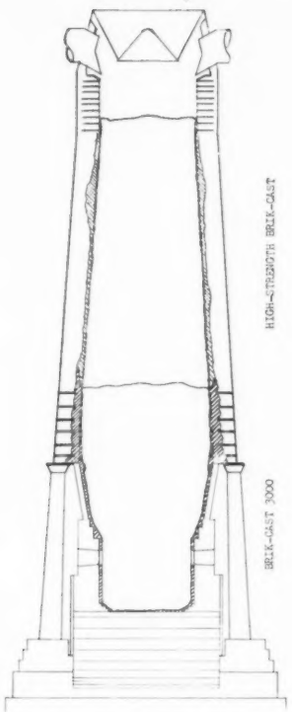
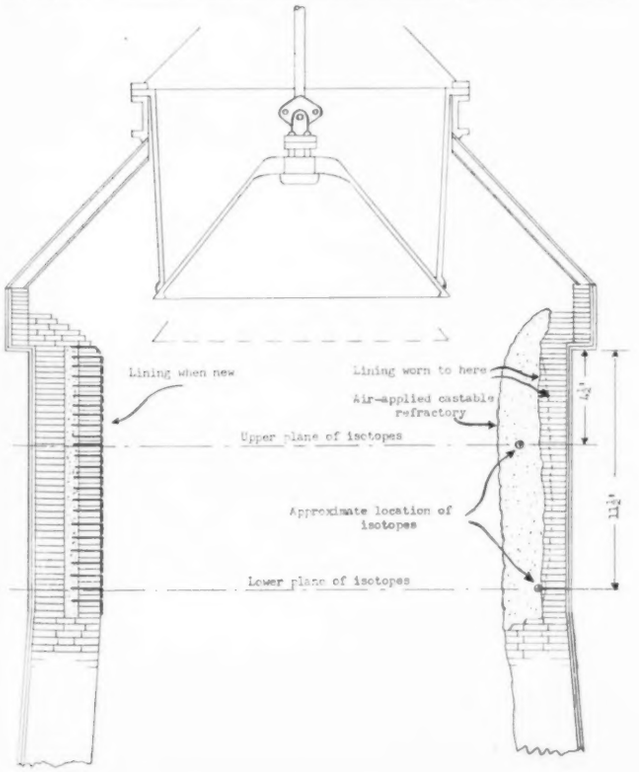


Figure 8 — Two types of refractory were used in patching the Birdsboro furnace.

lower locations are at about the bottom of the original throat armor. They are midway between the upper locations around the furnace and are buried at the face of the remaining brick. These positions give reasonably complete coverage around the furnace. The loss of the upper isotopes will indicate when half of the patch is gone; the loss of the lower ones will mean that all of the castable is lost. Figure 10 is a view looking down on the six locations. The upper sources are farther from the furnace shell and have a strength of 8 millicuries each. The lower ones are closer to the shell and are each 0.6 millicuries in strength.

Figure 9 — Sketch shows location of isotopes on F furnace.



The patching in F had proceeded to just above the upper plane of locations when the radioisotopes arrived. They were quickly checked out for number and strength, and then rushed to the furnace. A step was cut into the still-soft refractory an in. or two above the upper plane. Then at the proper distance from the face of the wall a hole was punched down to the level of the plane. The sources were removed from their shielded container with forceps and dropped into the hole. The hole was immediately packed with castable, and the castable wall built up at least a foot over the sources. The lower sources were placed the next day from a walkway on the outside of the furnace. Holes were cut through the shell, a 1-in. diamond core drill was used to make holes into the brick to the desired depth, and pipe couplings were welded to the shell around the holes. The sources were placed into balls of castable, Figure 11, the balls pushed to the back of their holes, the holes tamped full of refractory, and pipe plugs screwed into the couplings to seal the shell.

A Geiger-Mueller tube in a stainless steel shell is mounted on the outside of the furnace opposite each of the upper three sources, see Figure 12. A ratemeter for counting the radiation impulses is in the furnace foreman's office. It is connected by a power line and a signal line to each detector tube. This monitor has a 3-position switch so the foreman can check at anytime any of the detectors to see if the radioisotopes are still in place. The practice is to check before each cast. The lower sources are checked once a week with a portable counter; however, detectors for them soon will be wired into the monitor so they can be checked from the office along with the upper sources. Figure 13 shows one of the permanently mounted detector tubes and also the use of the portable counter. The background count at Pueblo varies from 25 to 50 counts per min. The detector at A location indicates around 400 counts per

Figure 10 — Isotopes are spaced equidistant around circumference of furnace.

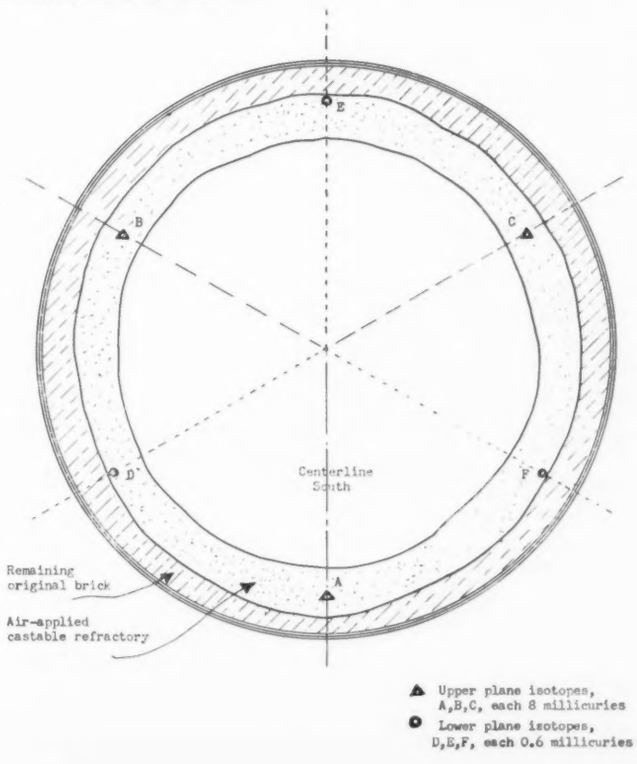


Figure 11 — Isotope for lower plane is placed in ball of refractory.

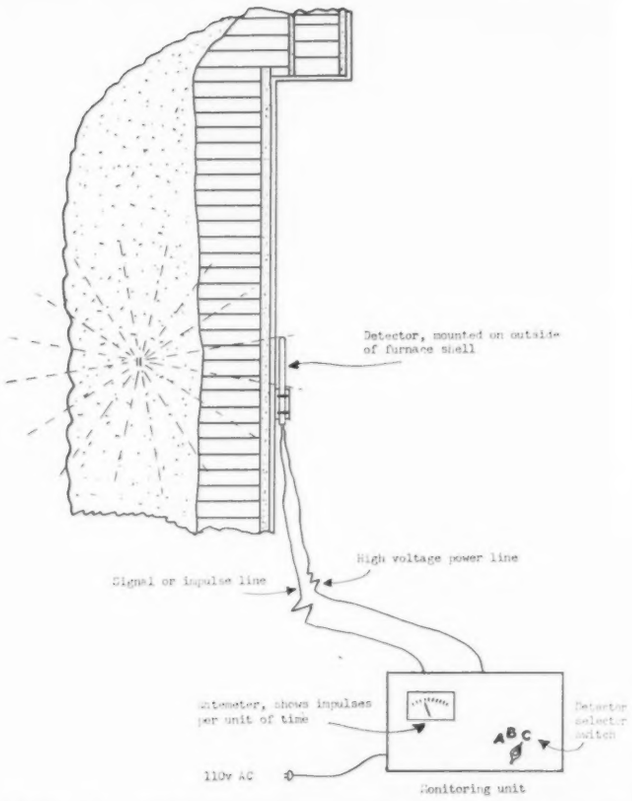

Detector, mounted on outside of furnace shell
High voltage power line
Signal or impulse line
Ratemeter, shows impulses per unit of time
Detector selector switch
A B C
110v AC
Monitoring unit

Figure 12 — Typical arrangement of isotope, detector and monitor.

min, B is 125, C reads 180, D shows 350, E is 400, and F has over 900 counts per min. All of these readings are several times the background count, therefore, there is no doubt about whether or not a source is still in place.

All people working within ten ft of the unshielded isotopes during the installation wore film badges as a check on radiation exposure. The badges later showed no detectable radiation. The blast furnace department has three dosimeters which show the amount of exposure to radiation. Unlike the film badges, the dosimeters can be read directly, are rechargeable and can be used indefinitely. When any person now works near the sources, he carries one of the dosimeters; however, the radiation hazard is practically nil. The strongest radiation, as mentioned previously, is from the isotopes at F location. This source may give out as much as 1000 counts per min, which is equal to 0.3 milliroentgens per hr, at the surface of the furnace shell. The allowable dosage according to present AEC regulations is 100 milliroentgens per week to the body in general, and 200 milliroentgens per week to the body extremities. There are 168 hr per week. The maximum dosage possible would be $(168 \times 0.3) = 50.4$ milliroentgens if a person was against the furnace at that exact location every min of the whole week. Moving away from a radiation source decreases exposure by the square of the distance, or moving twice as far away means receiving only one fourth the exposure.

Besides the radioisotopes in the furnace, a standard one millicurie sources is kept in its safe-handling container at the blast furnace office to check and calibrate the instruments. Blast furnace A, down for relining, will have twelve radioisotopes in its new lining in various locations from the mantle to the throat.

It is assumed that as a source is lost it will go down with the burden and melt and disperse in the pig iron.

Figure 13 — Portable counter can be used to check isotope sources.

When a source is missing from its location, the furnace foreman is to immediately call one of several trained people who will use the portable counter to monitor the pig iron, slag, flue dust and furnace gas. If detectable, the radiation will be followed through to the end product. Preliminary calculations indicate that the dispersion of the source in the pig iron, plus further dilution through the open hearth steel will reduce the level of activity to that allowable in drinking water. Probably the activity will be so low that it will not be possible to detect. However, efforts will be made to trace it so as to be sure there will be no health hazard, and so it will not end in a product where slight radiation might affect the customer's use of the material.

Isotopes still in place when the furnace is down for relining will be dug out and used elsewhere or disposal made according to AEC procedure. Probably each blast furnace at the mill will get a similar installation as it is relined. ▲

A pair of Reversing 2-High Rolling Mills –36" and 18"–

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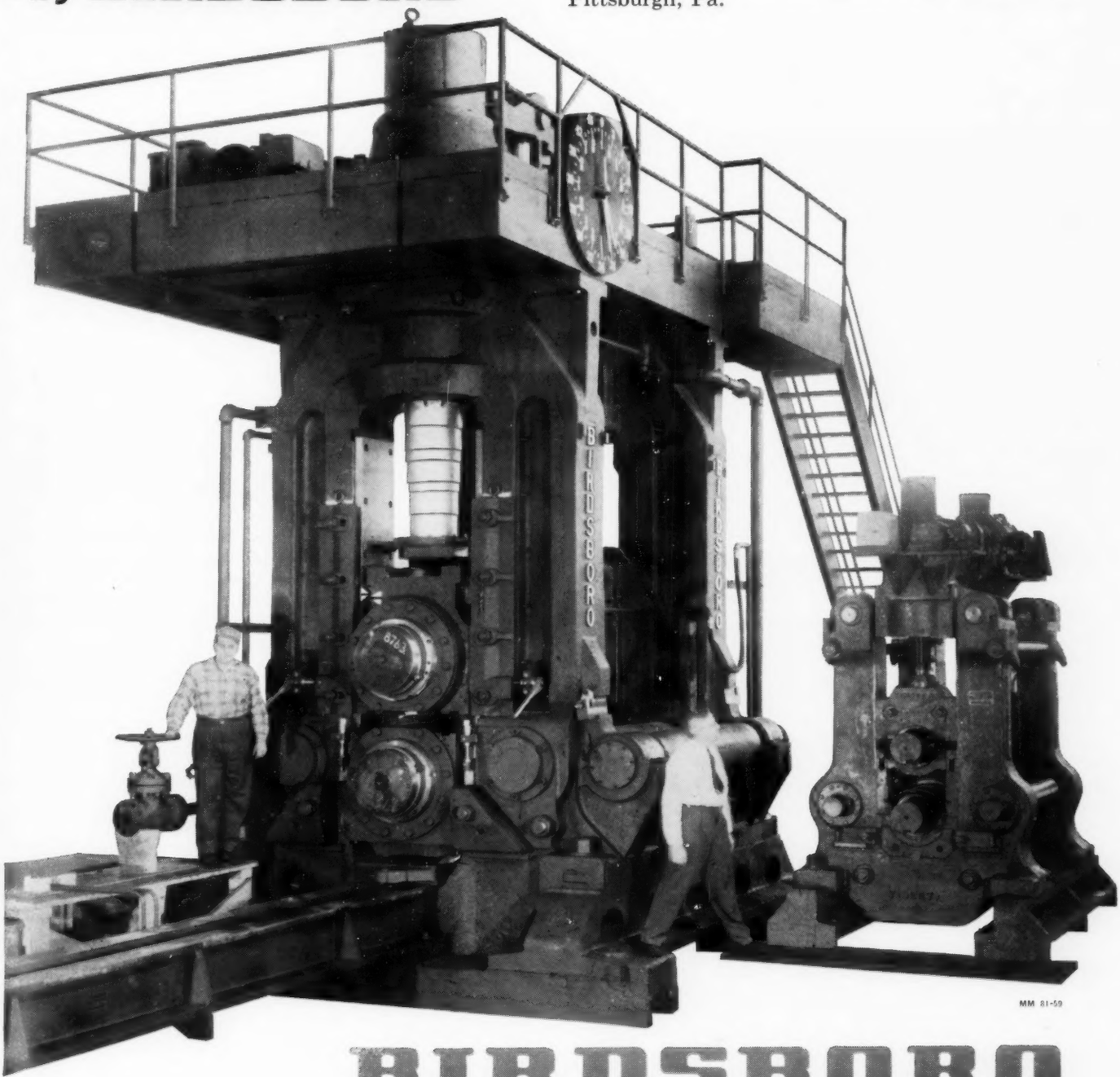
Regardless of variation, one factor remains the same, each mill is the successfully combined effort of the builder and the buyer—the experienced mill designer and the user. Each offers invaluable contributions to the successful operation of the installed unit. Each points the way to profitable productivity. *Sales Department, Engineering Department and Mfg. Plant:* Birdsboro, Pa., *District Office:* Pittsburgh, Pa.



MM 81-59

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Y. S. & T. Completes $60,000,000 Mill Project

Figure 1 — The revamped hot strip mill will meet requirements for larger coils. The mill is equipped to deliver 20-ton coils, rolled at a speed of 2250 fpm, up to 74-in. wide, 60 in. in diameter.

Figure 2 — Slabs up to 26-ft long can be heated in the three 5-zone reheat furnaces at the entry end of the enlarged 79-in. hot strip mill at The Youngstown Sheet and Tube Co.'s Campbell works. Each furnace has an effective hearth area of 28 x 100 ft, will bring slabs to 2400 F in 90 min. TV monitors keep operators informed of slab movement through the furnaces.

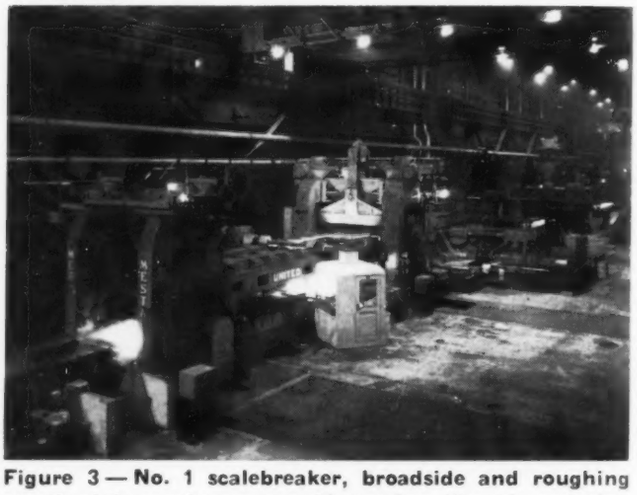


Figure 3 — No. 1 scalebreaker, broadside and roughing stands of the newly-revamped hot strip mill are in a portion of a 600-ft addition to the mill. Mill now extends more than 1400 ft from reheat furnaces to downcoilers. Some slabs are turned broadside before they enter the broadside stand to provide wide strip. Roughing stand work rolls are 42-in. diameter.

Figure 4 — Some 66,000 hp are needed to operate the 12 stands of The Youngstown Sheet and Tube Co.'s enlarged and modernized Campbell works hot strip mill. The motor room is served from a 138,000-volt substation atop the building. Four of the roughing stands have 6000 applied hp, and each of the five finishing stands has 5500 hp. Finishing stands were part of old mill but had larger drives installed.

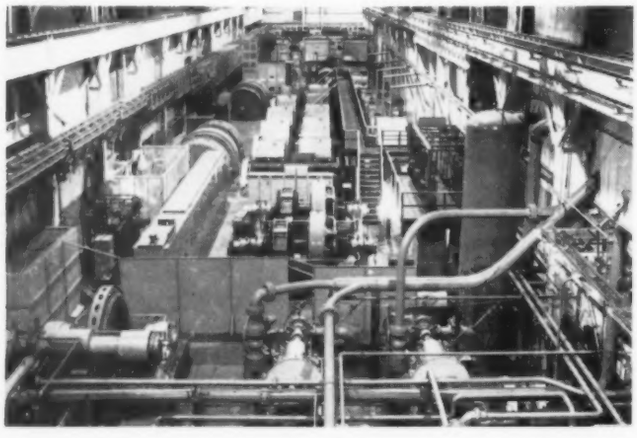
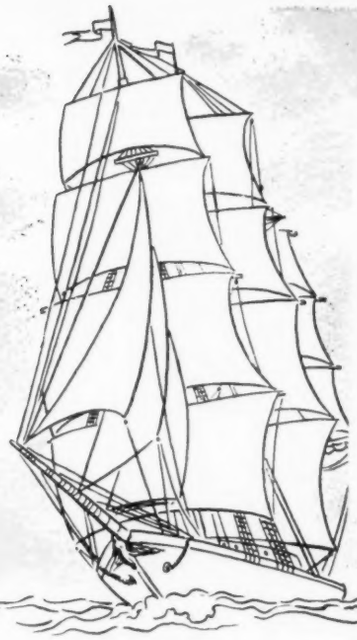


Figure 5 — In the new 50-furnace annealing facility in the Campbell works cold strip department are 42, 75-ton single-stack units with 126 bases, four 300-ton four-stack units with 12 bases and two 30-ton open coil furnaces with six bases. The annealing facility permits close control of the anneal process and replaces a department equipped largely with pack-type furnaces. A new 960-ft long building provides equipment for fast handling of coils.

Why Rust-Oleum is different—

and what this difference, backed by 35 years of industry proof, means to you!



A Sea Captain developed it . . . Industry proved it!

The original Rust-Oleum formula was developed nearly fifty years ago by Sea Captain Robert Fergusson, who became intrigued with the rust-stopping qualities of fish oil early in his career. Creating a *special treatment* for the fish oil, he used the *specially-processed fish oil* as the vehicle in combination with fine rust-inhibiting pigments. The result? A coating that actually *stopped rust* when applied directly over sound rusted surfaces, after scraping and wirebrushing to remove rust scale and loose rust. Possible, because the *specially-processed* fish oil penetrated the rust to bare metal. This was the birth of Rust-Oleum's *exclusive* 769 Damp-Proof Red Primer.

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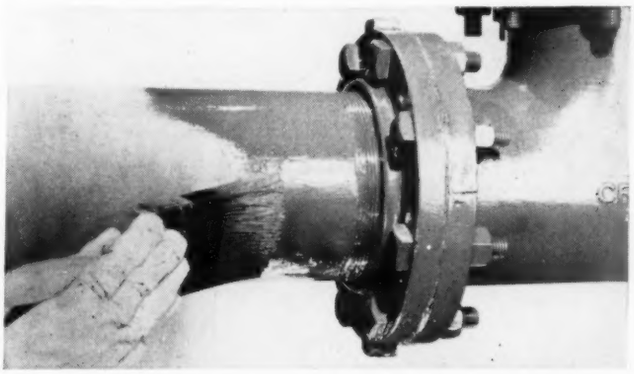
Today, Rust-Oleum in its many systems and colors, has been proved throughout industry for over thirty-five years. This proof by leading industrial users is your assurance of savings in time, money, and metal. Economies made possible by the fact that Rust-Oleum 769 Damp-Proof Red Primer goes right over the sound rusted metal—usually eliminating costly surface preparations. And Rust-Oleum, in its various systems, resists rain, sun, fumes, heat, weathering, chemicals, etc., for lasting beauty over the years.

RUST-OLEUM NEW COLOR HORIZONS SYSTEM

The Rust-Oleum New Color Horizons System introduces a new coating concept to industry. It combines four important factors: (1) the ability to stop rust, (2) smart, modern color harmony, (3) the durability to last and last, (4) ease of application that saves time, money, and metal. See how this system can bring lasting beauty to your plant, machinery, equipment, pipes, tanks, structural steel, fences, etc. Write for complete information or contact your nearby Rust-Oleum Industrial Distributor. He maintains complete stocks for prompt service.



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- ☐ Free test sample of Rust-Oleum 769 Damp-Proof Red Primer to be applied over sound rusted surface.
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How NBD product engineering produces better screw nuts

A report on centrifugally cast screw nuts and a new proof-ring inspection method

What makes a good screw-down nut? How long should it last? What causes early failure? When NBD product engineers were assigned the job of producing superior screw-down nuts, they asked these questions of blooming and slabbing mill operators. Answers varied greatly. "Good" life in one mill might be 1,000,000 tons of steel rolled. In another, life might be 4,000,000 tons — because of the peculiar operating characteristics of the mill. All agreed, however, that NBD's greatest contribution would be: (1) Production of screw nuts having maximum physical properties within the limits of the bronze alloy specified, and (2) absolutely sound castings, particularly in the critical threaded areas of the nut.

Evaluation method

Because of the recognized superiority of centrifugal castings for most applicable bronze designs, this method of manufacture seemed the logical approach to attain the desired screw-nut characteristics. Questions were

raised, however, in connection with the heavy metal sections of screw nuts, often exceeding 6". Would the mass effect of these heavy sections promote shrinkage or massive grain growth which would adversely affect tensile properties?

To resolve the questions, NBD product engineers made comparative tests on two 6,000-pound nuts, poured under identical controlled conditions from the same heat of NBD Alloy 65 N. (87½% Cu—11% Sn—1½% Ni). One was cast centrifugally. The other was cast in a chilled static mold.

Duplicate test sections were then cut from each casting, diametrically opposite each other, from several locations in the nuts.

TENSILE TEST RESULTS

Test Location	Tensile Strength, PSI		Yield Strength, PSI		% Elongation—2"	
	Centrifugal	Static	Centrifugal	Static	Centrifugal	Static
A	54,800	52,800	26,700	23,700	37.0	31.25
B	53,325	52,200	26,850	23,950	30.25	34.5
C	51,800	46,600	26,750	23,900	22.0	23.0
AVERAGE	53,308	50,533	26,767	23,850	29.75	29.58

HARDNESS READINGS

Hardness readings were also made on slices cut from the nuts, near the top, center and bottom. These readings, taken at 1" intervals from the O. D. to the I. D. were as follows:

BHN Hardness—500 kg Load

	O. D.	1"	2"	3"	4"	5"	6"	I. D.	Average
Centrifugal	98.5	99.0	94.5	96.5	98.0	99.5	95.0	97.0	97.25
Static	100.0	99.0	97.0	96.0	92.5	87.0	88.0	90.5	93.75

Micro and Macro Studies

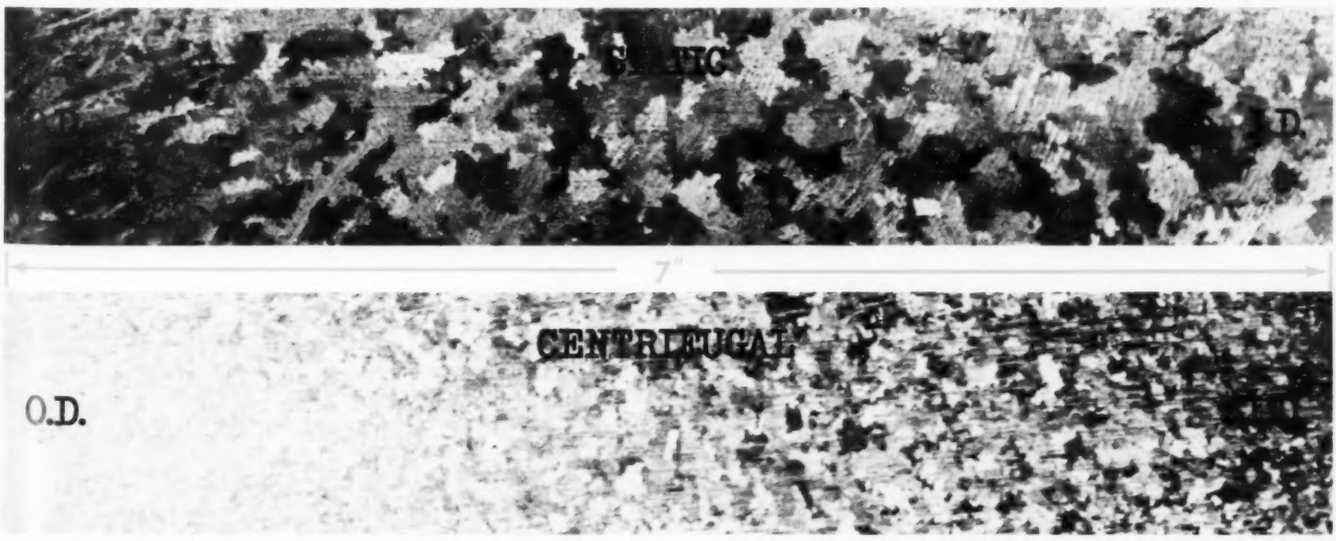
Micro and macro studies further strengthened the case for centrifugal castings, particularly in the critical I. D. of the screw nut. Note the pronounced finer grain in the centrifugal macrophotograph.

Proof-ring assures 100% quality

While the foregoing tests proved the superiority of the centrifugally cast nut — one big question remained: How could NBD customers be absolutely positive that every screw nut purchased was dense, sound and strong in the important threaded area? Visual inspection was not the answer. Dye-check, used extensively by NBD, was only partially effective. X-Ray was not practical because of the heavy metal sections involved.

From this enigma came a unique solution: a proof-ring which *exactly* duplicates the quality of the thread area of the casting. Without damaging the nut in any way, the proof-ring may be chemically analyzed, fractured, studied microscopically or otherwise tested. The proof-ring can be shipped to customers for evaluation — enabling them to inspect the nut quality — prior to its shipment.

The NBD sales engineer is prepared to give you more details on this proof-ring testing method. For further details on this unique proof-ring inspection technique, contact an NBD sales engineer, or write us.



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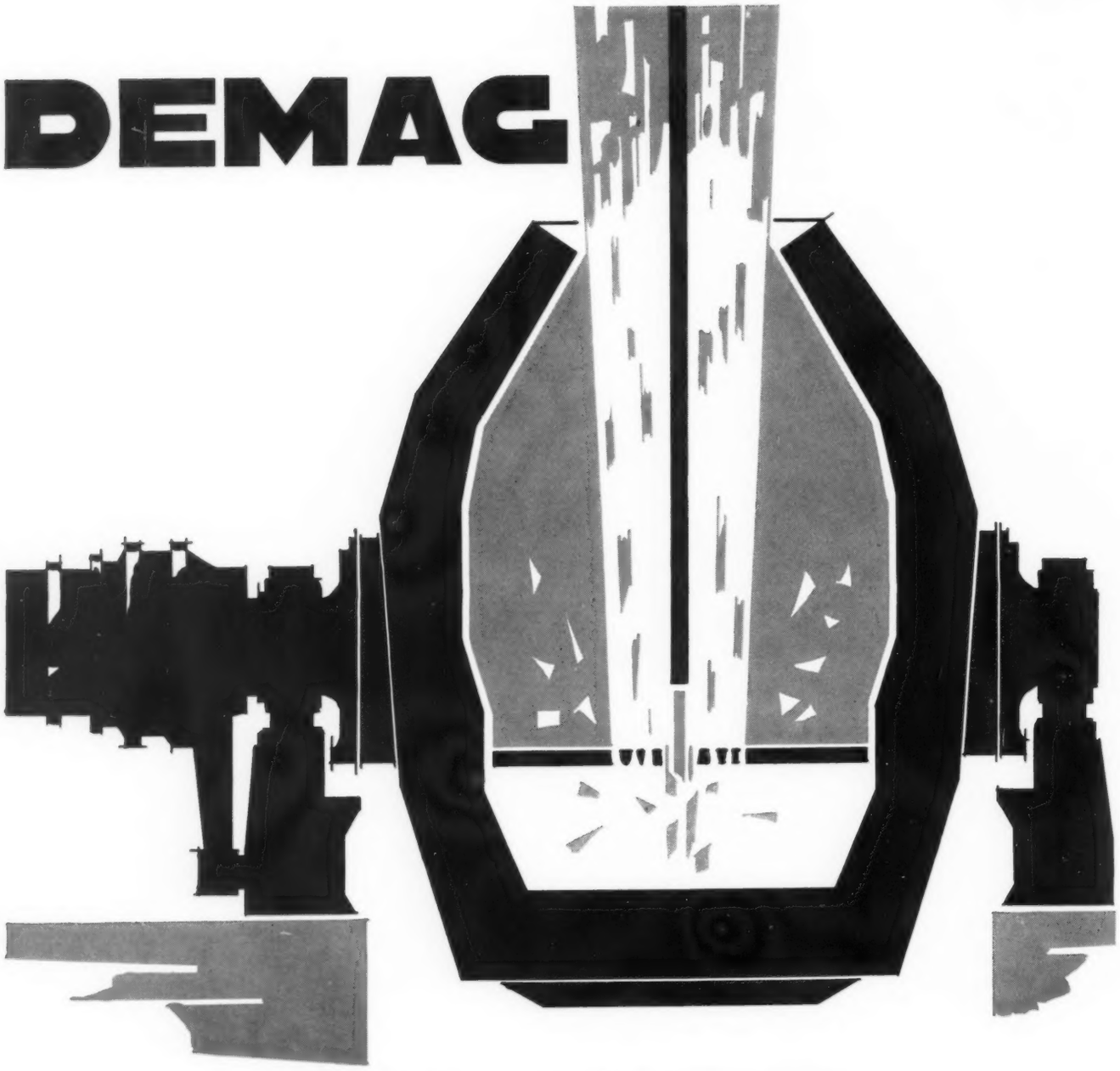

Milestones in Oxygen Steelmaking LD

The LD-Process started a revolution in steelmaking. DEMAG has played a leading part in this development, including the building of 5 to 175 metric ton LD furnaces and the design of super LD furnaces from 250 to 300 tons. Further new developments typical of DEMAG's work in oxygen steelmaking include:

LD-AC Furnaces • Rotor Furnaces • Kaldo Furnaces

AMERICAN DEMAG CORPORATION, ONE GATEWAY CENTER, PITTSBURGH 22, PA.

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Tape Controlled Grinder Determines Roll Finish Diameter

COMPLETE automation of a 60-in. heavy-duty roll grinder under punched-tape control has been accomplished for the first time by the Farrel-Birmingham Co., Inc., and the General Electric Co. This precision grinder will finish work rolls for metal rolling mills. It will automatically grind straight or crowned rolls up to five ft in diameter to exacting tolerances of diameter and straightness and also duplicate diameters for pairs of work or backup rolls.

Benefits to the steel mill are the machine's ability to produce extreme repeatable accuracies, permitting mill management to fix and maintain definite standards of regrind procedures, and the important economy of longer roll life which results from the fact that removal of stock is automatically held to minimum in the regrinding operation.

Similar in theory to the punched-tape numerical control used with modern machine tools for "flexible automation," the roll grinder control uses servo-controlled positioning of probes to measure the diameter and profile of rolls being worked and to detect work remaining to be done.

Inherent features of the Farrel-Birmingham machine, plus the nature of the grinding operation, make it unnecessary to use numerical positioning of the grinding wheel itself.

Operating from standard 1-in. punched tape, the automatic control will direct the grinder through a complete cycle, performing all operations necessary to refinish a roll. Once the operator starts the grinding wheel and pushes a "cycle start" button, the machine and control system, as programmed, take over the work of rough grinding, alining the workpiece, semi-finishing, dressing the grinding wheel, finish grinding and finally measuring and recording a printout of roll size.

To do this, the control initiates 17 specific machine and control operation sequences as primary functions. It orders four other sequences as secondary functions, depending upon the state of specific machine devices. It directs two servo-controlled motions, two variable-speed motions, one fixed-speed motion and their associated devices. It selects any of ten speeds for the machine headstock, carriage, grinding wheel, step infeeds and continuous infeed rates. For wheel dressing, it selects any of six combi-

Figure 1 — Probes scan each roll to find the minimum diameter, prior to determining finish size.

nations of diamond positioning and crossfeed.

Special features in the automatic control will match the diameters of both work rolls in a mill-stand pair, irrespective of original diameter or uneven wear.

Automation of the roll grinder was made possible by the addition of a probe table opposite the grinding wheel carriage.

Through the sophisticated control, servo-positioned hardened steel probes scan each new roll to find the point of greatest wear and automatically set this as a "benchmark" for the rough grinding operation and determination of finished diameter.

Similarly, the control memorizes the finished diameter of the first roll and matches the finished diameter of the mating roll to it automatically. This check is made positive by the probes against the actual work surface rather than measurement of the position of the grinding wheel.

Another advanced feature of the automatic system is made possible by the "trunnion-tilt fine infeed" arrangement used to mount and control the grinding wheel. The wheel is tilted into the work with the support and leverage of trunnions, eliminating "stick-slip" effects of way friction and allowing precise positioning of the grinding wheel against the work in increments as fine as 0.0001 in. Since the system is always preloaded in one direction, positive infeed and withdrawal of the grinding wheel can be accomplished with extreme accuracy.

With the General Electric control, this feature is used both to step the wheel forward into the work and to continuously infeed the wheel to compensate for wheel wear. Any of ten rates may be programmed for each function.

Since mill rolls normally show greatest wear in their center portions, the probe table finds the minimum diameter here. To reduce the higher end surfaces of the roll to this diameter, the control first orders a special sequence known as "short stroking."

By means of the "wheel approach" program address and the trunnion-tilt fine infeed, the wheel closes to the work until the control senses that it has picked up a slight load. This is sensed by detecting variation in the grinding wheel motor amp. The wheel then is traversed to the near end of the roll, steps in according to program, automatically retraces its course until it loses load, and steps in again, repeating this operation until automatic checks within the control sense that this end of the roll is within the programmed number of thousandths of the minimum roll diameter. The wheel then retracts and moves to the other end of the roll to repeat the short stroking.

The roughing cycle is then continued by means of a programmed sequence called "continuous carriage traverse," which automatically passes the wheel back and forth across the face of the roll until it is within the preselected tolerance from the desired diameter.

At this point, the grinding wheel is diamond-dressed, if programmed, and finish grinding is made to final tolerance with individual speed changes programmed for headstock, wheel and carriage drives to produce the desired finish.

After initial familiarization it is expected that the automated roll grinder will materially speed up roll grinding operations.

Assuming proper mill setup, better matched rolls will produce more uniform strip from the rolling mill and will increase service life of each pair of rolls between regrindings.

Thus, the mill operator will simultaneously reduce operating expense and increase yield from his mill.

The first three of these automated grinders will soon be in operation at the new hot mill of Great Lakes Steel Corp., a division of National Steel Corp. ▲

Quick Replacement Tips for Oxygen Lances

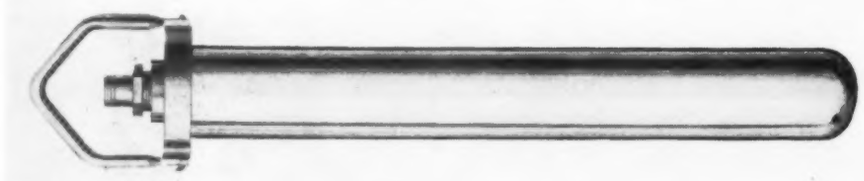
AN IMPROVED line of oxygen lances with quick-replaceable tips has been developed by the Hutton Fabricating Mfg. Co.

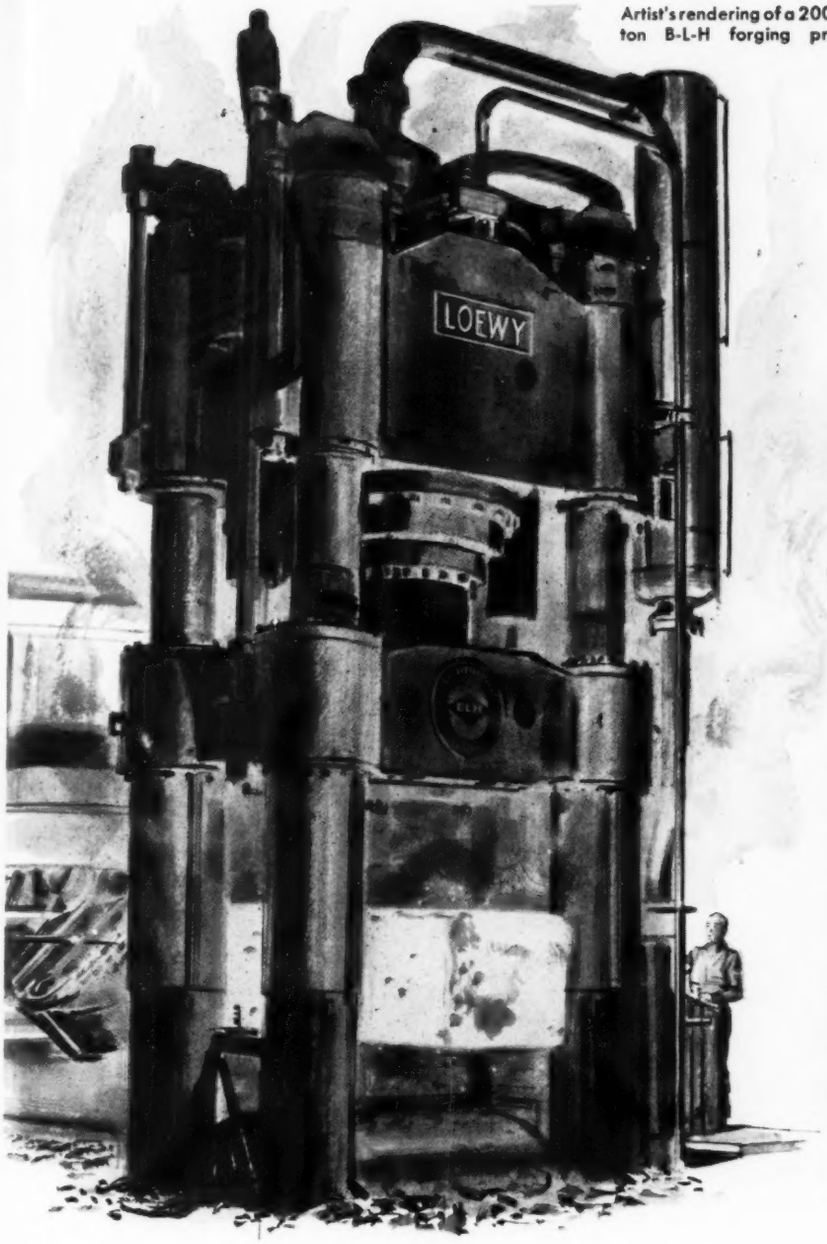
The lances have been designed to eliminate all sliding and bolt connections so that the tips can be easily replaced after completing their life cycle. The tips have only one connection, and a lance can be renewed with a replaceable tip in less than an hr.

These lances are made in any length depending upon the user's furnace application. Standard tips are copper or stainless steel. Forged tips, as well as tips to specification are also furnished. All tips are designed with an oxygen fed pipe held on a 20-degree pitch.

Hutton has developed an improved water-cooling system for these lances that concentrates the coolant at the critical points of the tip. A Great Lakes area mill superintendent reported that depending upon the water condition he had been obtaining from 200 to 400 heats from each lance before tip replacement is required, as compared to 80 to 100 heats from earlier designs of lances. ▲

Figure 1 — The oxygen lance tip can be changed in less than an hr.





Artist's rendering of a 2000-ton B-L-H forging press

World's largest forging press, designed and built by B-L-H and now producing nuclear, rocket and turbine parts

From B-L-H Loewy forging presses... metallurgical excellence and optimum speed

Ideally, you want genuinely fine quality forgings and you want to make them at a high production rate. B-L-H Loewy presses meet both these requirements.

Today your customers are demanding steels free of segregation, clean and homogeneous, flawless and uniform in structure. These are precisely the steels produced on B-L-H presses, steels that possess, as one of our customers said, "internal qualities never before achieved."

Note some specific features of B-L-H forging presses:

- Fast closing, working and return speeds that reduce idle time and prevent heat loss in the workpiece
- Modern control systems that permit instantaneous selection of working cycles
- Strokes per minute for planishing unsurpassed by any other type of forging equipment
- Ability to outproduce hammers in working specialty alloy steels
- Provision for variation of pressure, tonnage and speed within a wide range
- Heaviest eccentric loading
- Full accessibility of tooling, easy supervision and maintenance

B-L-H builds presses for free forging, open die forging, and closed die forging, for hot and cold working of all kinds of metals—ferrous and nonferrous, rare, nuclear and exotic. These machines are available in all capacities from 500 to 50,000 tons or more. B-L-H also designs and builds manipulators and accumulators. For further information, write Dept. C-8.

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Industrial Equipment Division · Philadelphia 42, Pa.

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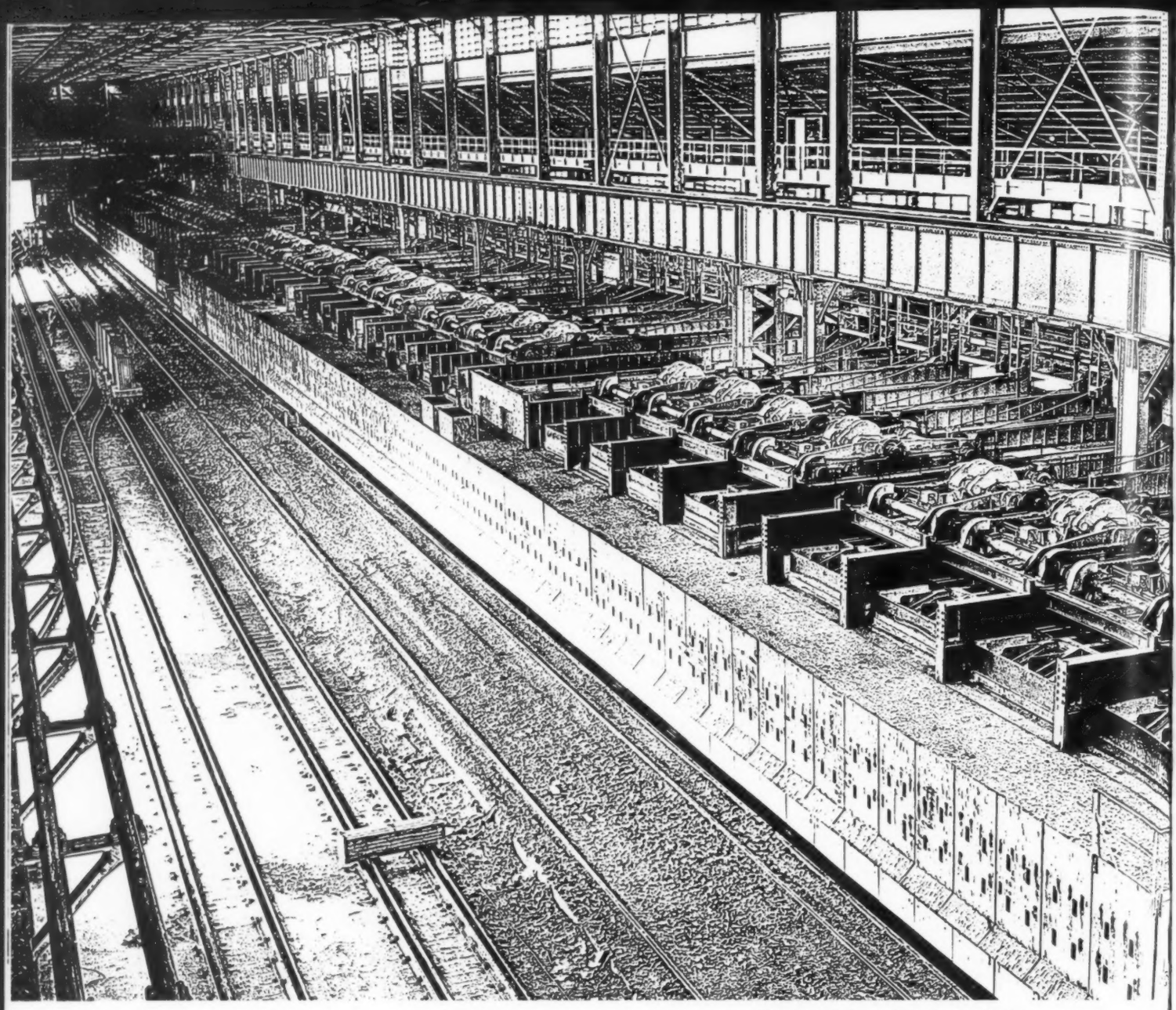


Courtesy of Gary Works, U.S. Steel Corporation

Gets them out the back door (750 tons/hr) This is the largest installation of soaking pits (48) ever built at one time. Engineered by Surface, it will heat an average of 750 tons per hour. At peak capacity, it loads the ingot buggies at a rate of 1200 tons per hour. A dual recuperator system applies the maximum amount of heat where it belongs—inside the pit. Address inquiries to 2404 Dorr St., Toledo 1, Ohio.

SURFACE

SURFACE COMBUSTION, Toledo 1, Ohio/ a division of Midland-Ross Corporation MR

Refractory Placement System Speeds Furnace Repair

A PNEUMATIC system for handling dolomite, lime and ore that represents a significant advance in materials handling and helps speed the open hearth steelmaking process was announced by Blaw-Knox Co.

The system, a combination of new material transportation and a proved placement method, incorporates centralized off-the-floor storage bins, blowers and activators at lower furnace level, pneumatic delivery to a cyclone designed receiver, overhead monorails, batch hoppers and a mechanical thrower to place the refractory material onto furnace walls.

The two primary advantages of the new system are that it clears the charging floor of material and handling equipment, and frees hot metal cranes for other vital functions.

Significant improvements were made over the conventional "batch" conveying systems to make it especially suitable to open hearth service. A new valve was developed for the inlet to the pressure vessel which provides an airtight shutoff and is capable of closing against a head of material.

This makes the system adaptable to use with large storage bins. A single pressure vessel can be used to convey different materials from a number of storage bins.

A new valve at the outlet of the pressure vessel provides a means for controlling the volume of material conveyed. This valve can be automatically controlled or it can be set manually to provide the desired flow.

This valve provides an additional advantage. Since it is interlocked to open only after the flow of conveying air has started, there is no slug of material in the line, a condition which quite often leads to a plugged system.

The conventional throwing mechanism is used, with an air motor. The speed of the throwing mechanism has been increased to insure capacity to *throw to any point in the largest open hearth.* A speed regulating means is provided to control the stream trajectory and the mechanism is universally mounted so that

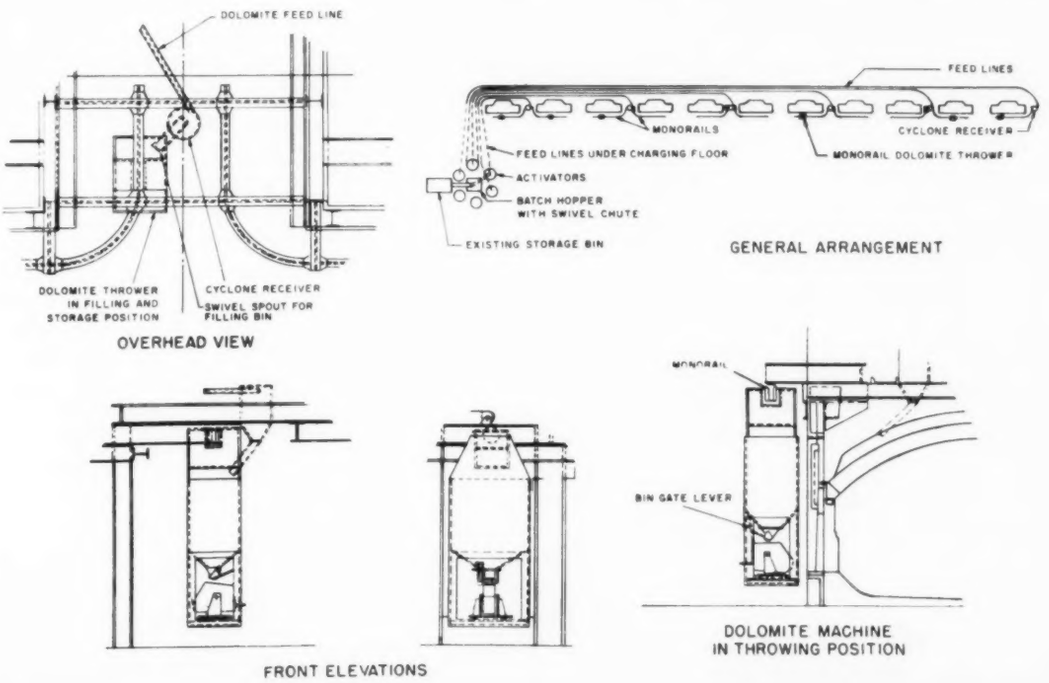
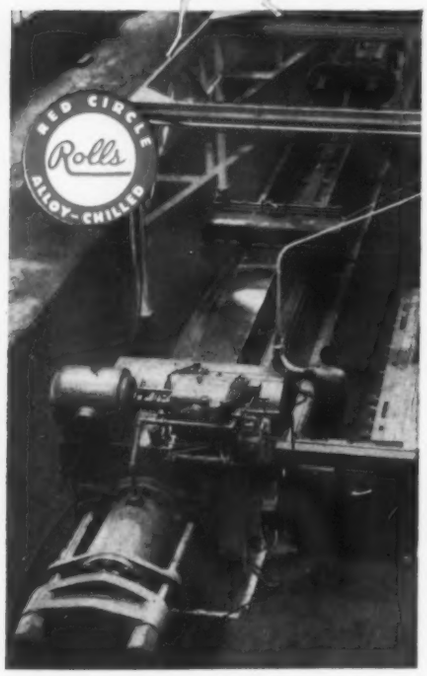


Figure 1 — The schematic layout indicates the placement of the feed line piping and the operating and storage positions of the throwing machine.

Hyde Park
STRETCHER
LEVELLERS



Hyde Park Levellers have a complete range of stretching capacities from 150 to 1250 tons—for levelling ferrous and non-ferrous sheets in sizes up to 120 inches wide by 500 inches long.

Adaptable for automatic cycling.

Pneumatically or hydraulically operated wedge or toggle type jaws.

Hyde Park
FOUNDRY AND
MACHINE CO.
HYDE PARK
Westmoreland
County, Penna.

Rolls
Rolling Mill Equipment
Gray Iron Castings

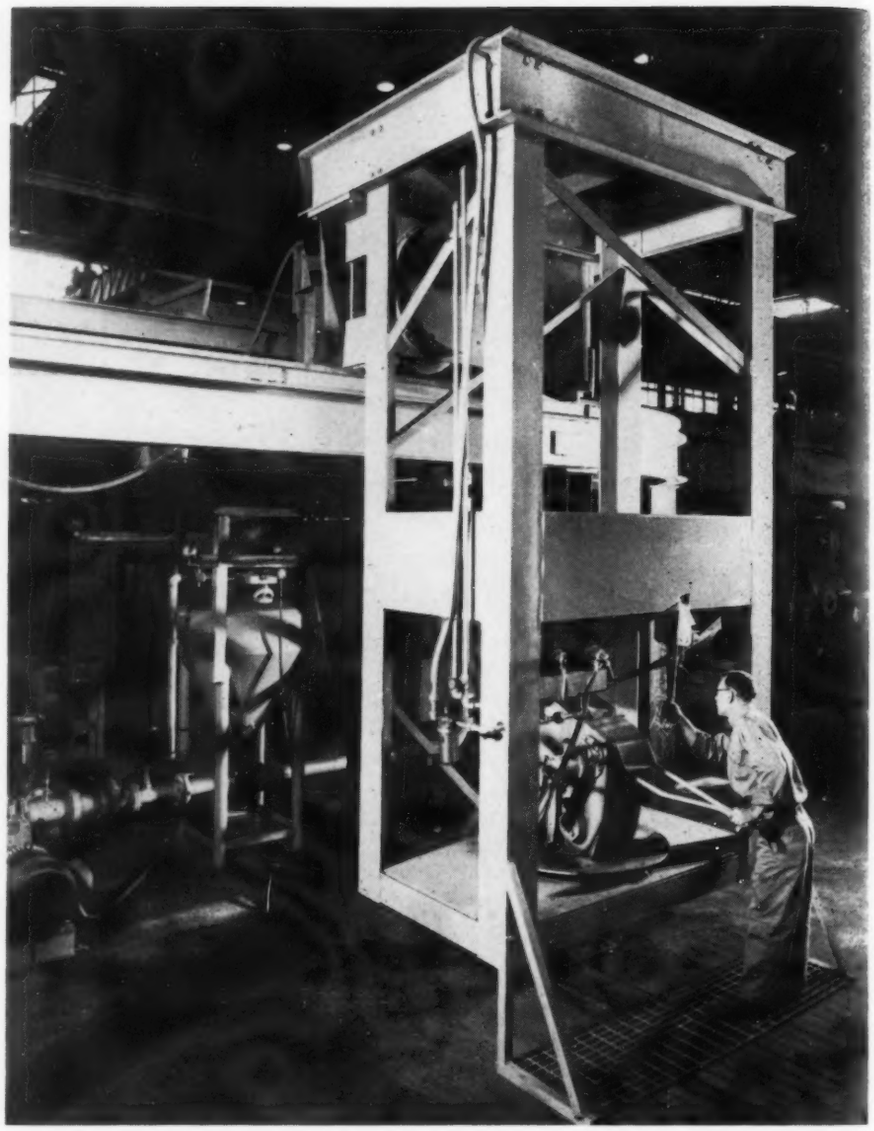


Figure 2 — The hopper of the throwing mechanism holds enough dolomite to make up a furnace.

the stream can be raised or lowered in elevation and moved to right or left.

Pneumatic material handling can be employed comprehensively, or to supplement existing handling methods and equipment.

A prototype of the new system, designed and fabricated in one of the firm's plants utilizes storage bins that deliver measured amounts of material to activators. One activator, or pressure vessel, is planned for every two furnaces.

A combination of gravity plus low-pressure blowers moves material pneumatically through steel piping just under the charging floor and then vertically to cyclone receivers, one of which is positioned furnace high between two open hearths. Ore and lime would be fed through lances under pressure directly into the bath. Use of a cyclone design for the receiver, which can vary in diameter and depth, permits the pneumatically-fed dolomite to drop by gravity through a swivel spout to the throwing mechanism, eliminating any dust problem. The hopper of the prototype unit handles 175 cu ft, or eight tons, but batch capacity can be varied.

Air power moves the hopper-throwing mechanism over the monorail at a maximum speed of 176 fpm. The entire unit assumes an elevated position after dolomite placing to permit immediate walk-under clearance of seven ft.

The hopper's capacity is sufficient to "make up" a furnace, and the unit is equipped with indicators to show when push-button refilling is required at any one of the cyclone receiver stations. ▲

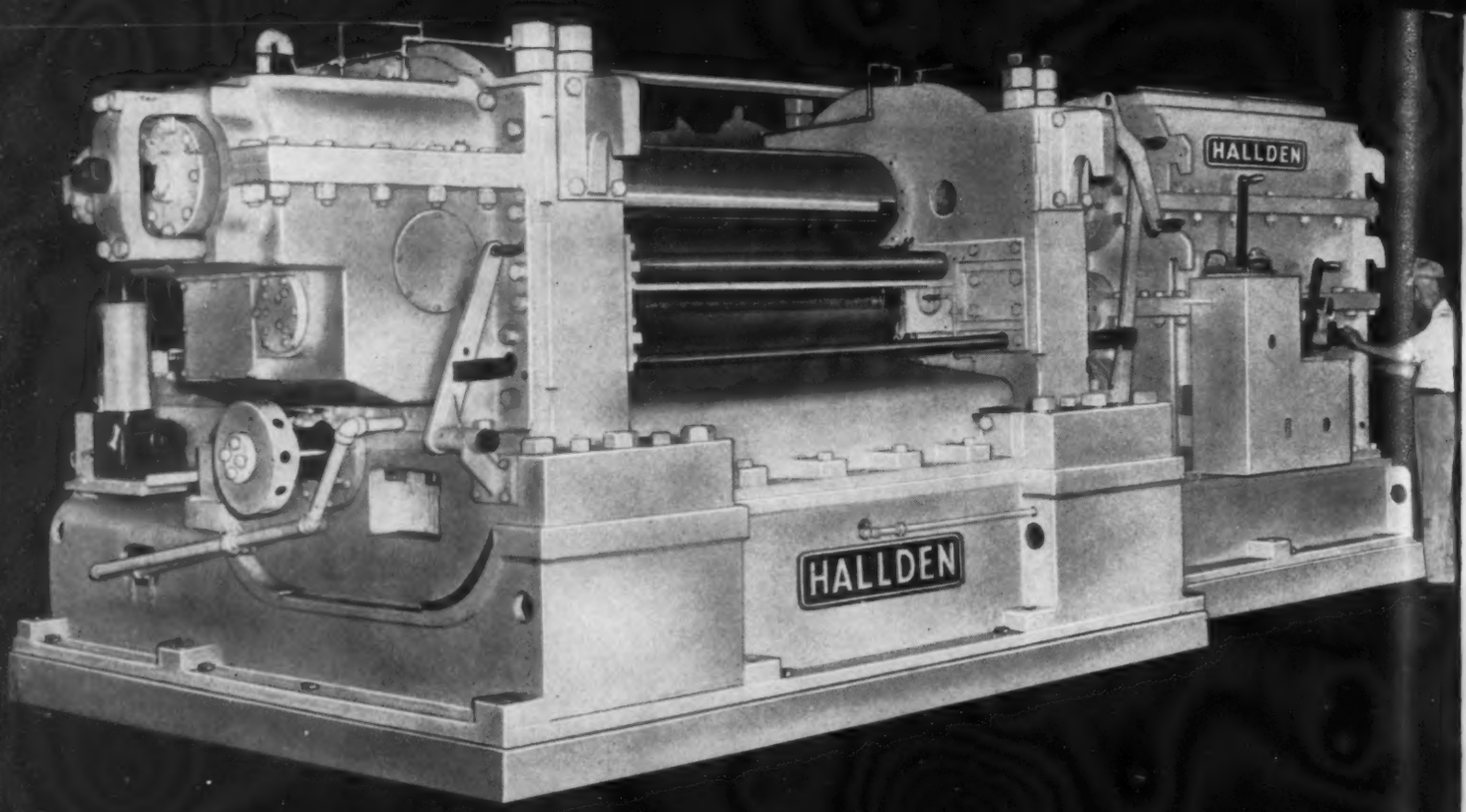
HOMESTEAD® LUBRICATED PLUG VALVES

They keep right on working when ordinary valves have to be replaced. Why? For several reasons. First, because of very close tolerances between sealing surfaces of the plug and body (.002″ clearance on small sizes, and .005″ to .007″ on the largest sizes). Second, because of their *controlled* pressurized lubrication system which guarantees complete coverage of all sealing surfaces, provides chemical seal against leakage and protection against corrosion. Add to these the positive plug-freeing action which occurs with each lubrication, and it's easy to see why Homestead Lubricated Valves last. Get the complete story. Send for Reference Book 39-1; and for the assurance that quality brings, specify Homestead Lubricated Plug Valves.

hv

HOMESTEAD VALVE MANUFACTURING COMPANY
"Serving since 1892"
P. O. Box 160, Coraopolis, Pennsylvania

Makers of: Homestead Ball Valves, Cam-Seald, Lever-Seald and Lubricated Plug Valves.



SYNCHRONIZED ROTARY SHEET SHEARS

Combine Accuracy, Speed, Durability

- **Infinite length-of-cut control**
- **Full synchronization**
- **Minimum adjustment**
- **Reliable performance**

All these features are assured by such Hallden design extras as hardened torque correcting surge gears, dynamically balanced components, precision fitted parts.

Hallden shears are engineered and built to meet the requirements for the most modern high speed strip processing lines.

For custom designed synchronized flying shears for all high production strip shearing, consult Hallden, the worlds foremost designers of flying shears.

HALLDEN

The world's leading machinery manufacturers rely on Hallden shears in their process lines

THE HALLDEN MACHINE COMPANY • THOMASTON, CONNECTICUT

Associates: The W. H. A. Robertson & Co., Ltd., Bedford, England

Gripping Force Supplied By Unusual Hydraulic Circuit

by RICHARD L. STUCKEY

Hydraulic Engineer, Alliance Machine Co., Alliance, Ohio

THE 75-ton capacity straight line forging manipulator recently designed and built by The Alliance Machine Co. is the largest of its type. This machine with the aid of special overhead forging cranes will manipulate forgings as large as 300 tons during the forging operation. The operation of the tongs and the slewing, or alining of the peel with the centerline of the machine, is supplied by a hydraulic power unit. The hoist, leveling, tongs revolve and travel motions are mechanically operated.

The hydraulic unit is so designed that the valves are mounted on a drilled manifold, which is mounted on the reservoir. This type of mounting makes the valves easy to service and replace without disturbing the piping. Manifold mounting also eliminates many pipe joints and thus reduces leaks. Besides the manifold mounted valves, there is an electric motor and two pumps mounted on the 200-gal reservoir.

Figure 1 — The hoisting mechanism and the tongs revolve are powered by mill type motors through suitable gear reductions.

The force of over 400,000 lb, with which the tongs of the forging manipulator grip the workpiece, is supplied by a unique high-low hydraulic circuit, incorporating a booster circuit as part of the 21-in. bore, rotating cylinder. A 75-gpm flow rate, and operating pressures of 1800 to 2100 psi are required in the grip cylinder. Large hoses were required to transfer the fluid power from the main frame to the peel, which could move to any position, 40 in. side ways, 17 in. front to back in the horizontal plane and 96 in. in the vertical plane. Large hose loops with swivel joints at each end were used; the swivel joints prevent twisting of the hoses due to the various movements of the peel.

The size of the hoses, the machine movement and the shock loads encountered on the manipulators were so great that engineers decided against running the full pressure, required to operate the grip cylinder, through the hoses. Instead, a booster circuit was employed as part of the grip cylinder, which was further complicated by the fact that the grip cylinder rotates at 3.5 rpm, thus requiring the oil to pass through a rotary distributor. Full control of the booster circuit was thus confined to two lines.

The booster circuit consists of a

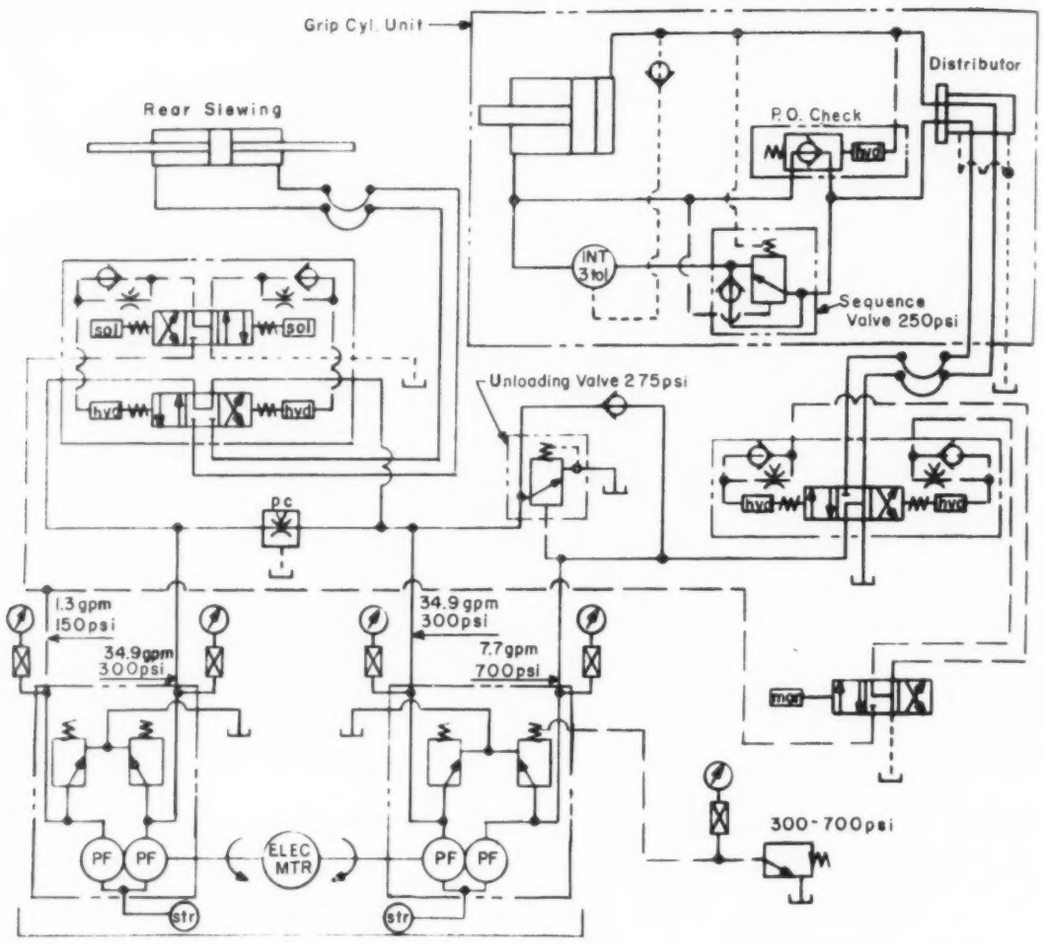


Figure 2 — The hydraulic circuits used are illustrated schematically using JIC symbols.

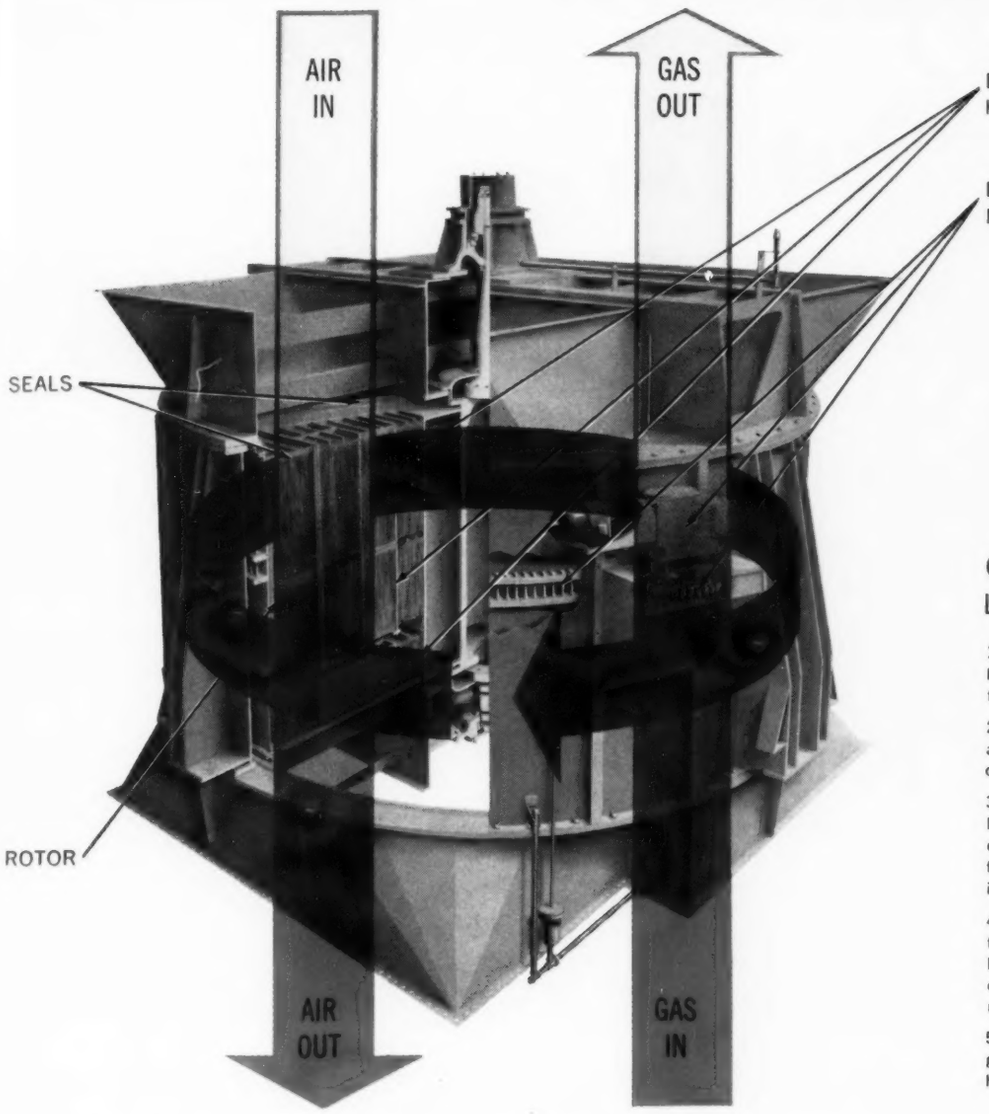
three to one booster, a pilot-operated check valve with decompression features, a sequence valve with free flow return and a check valve. The booster valves are mounted on the manifold block between the distributor and the cylinder. These subplate mounted valves eliminated a great deal of external piping. When the booster circuit is in operation, oil flows through the distributor to the rod end of the cylinder, passing through the pilot-operated check valve. As the tongs engage a workpiece, the piston movement stops and the pressure increases. At 250 psi the sequence valve opens allowing flow to the booster. Oil then flows to the rod end of the cylinder from the booster at three times the input pressure. The exhaust oil from the booster returns through the check valve, entering the line between the head end of the cylinder and the distributor.

To open the tongs, oil flows from the distributor to the head end of the cylinder, building up pressure immediately. Oil flowing through a pilot line to a pilot-operated check valve opens a poppet in the pilot-operated check valve allowing decompression of the oil on the rod end of the cylinder, and then fully opening the valve to allow the oil to return to the reservoir through the distributor. Check valves and checks built into the booster prevent the oil from flowing through the booster in the reverse direction. Check valve in sequence valve relieves pressure on the input side of the booster.

The intensity of the grip on the workpiece can be controlled by a remote-controlled relief valve located in the operator's cab. This valve vents the main relief valve of the small volume, high-pressure pump. A 4-way valve for controlling the grip motion is pilot operated by a small master 4-way valve located in the operator's cab. This arrangement prevents dropping a workpiece during the forging operation, which could happen with a solenoid controlled valve, in the event of a solenoid burn-out.

The slewing cylinder is controlled by a solenoid, pilot-operated 4-way valve, a flow control valve regulates the speed of the slewing cylinder by using a bleed-off circuit. Oil bled off through this valve is piped to the reservoir line of the 4-way valve making it available for rapid advance of the grip cylinder. Hydraulic shock is reduced in both the grip and the slewing motions by the use of pilot chokes to control the speed of the spool shift in the 4-way valves.

Slewing, leveling and grip motions are ideally suited to hydraulic operation, but in this machine screw leveling was preferred. The hoist mechanism is operated by a mill motor driving the hoist drum through a gear reduction. The tongs revolve is powered by a mill motor operating through a gear reduction and a special clutch arrangement to prevent damage to the mechanism due to sudden stops or starts. The travel motion is powered by two independent motor and worm reductions that are electrically synchronized. Each drive has its own hydraulic brake operating from a single station. All other mechanically driven units are equipped with electric brakes. ▲



Cutaway shows how Ljungstrom® works

1. Ljungstrom is enclosed in gas tight housing with seals to separate flue gas and air.

2. Flue gas and combustion air pass axially through Ljungstrom in continous counter flow.

3. Rotor revolves slowly through both flue gas and air stream, continuously absorbing heat from flue gas and releasing it to incoming air.

4. Heating surface consists of many formed metal sheets packed in rotor. Elements are packed in baskets for easy inspection, removal or replacement.

5. Units can be arranged for vertical gas flow (as shown) or for horizontal flow.

HERE IS A WAY TO RECOVER AS MUCH AS 1000°F FROM FLUE GAS

. . . and cut your fuel costs 1% for each 35° - 40°F recovered!

More complete combustion . . . higher furnace temperatures . . . increased furnace capacity . . . improved product – these are established advantages of preheating combustion air. And the Ljungstrom® Air Preheater, *on the basis of fuel savings alone,* deserves careful investigation. For it is *the* most efficient metallic heat exchanger ever developed. It can recover as much as 1000°F from flue gas, with savings in fuel costs of 1% for each 35° - 40°F recovered.

High efficiency in extremely small space

The Ljungstrom rotor revolves continuously through the flue gas and incoming air . . . absorbs heat and releases it from *the same surface.* Since heat does not have to pass *through* the heat exchange surface, the Ljungstrom is remarkably efficient and compact. A unit measuring 5′ x 7′ x 8′, using 2000°F flue gas diluted to 1500°F, can handle a furnace exhausting 30,000,000 Btu/hr and raise incoming air from 70°F to 1400°F.

Applications in the steel industry

Ljungstroms can perform efficiently in many steel-making applications: reheat furnaces, soaking pits, slab, billet and skelp furnaces. Used in series with checkers they can provide far higher and more uniform preheating than any other heat exchangers now in use.

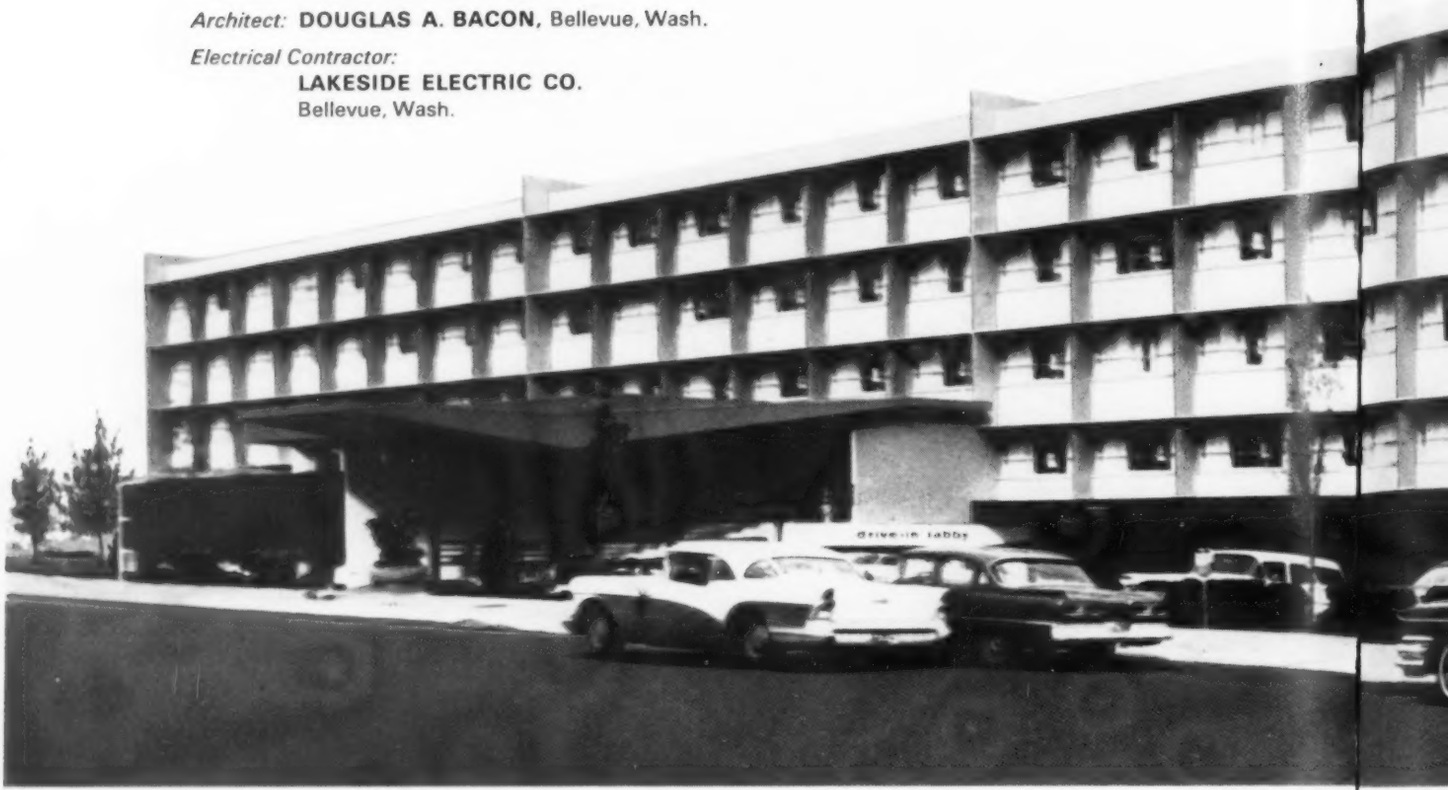
Tested and proved under all conditions

Ljungstrom's continuous rotary regenerative principle has been performance-proved for more than 35 years in over 3500 units. The electric utility industry (highly conscious of fuel costs) has virtually standardized on Ljungstroms. *Every* major U.S. utility is Ljungstrom equipped, with some units in continuous service since 1923. Refineries, chemical process plants – even ocean liners and cargo vessels – save fuel with Ljungstroms. For more information on how Ljungstroms can benefit you, write:

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N.Y.

Owner: **DORIC CO.**, Seattle, Wash.
Architect: **DOUGLAS A. BACON**, Bellevue, Wash.
Electrical Contractor:
LAKESIDE ELECTRIC CO.
Bellevue, Wash.



Electrical Protection goes MODERN *with* BUSS Fuses . . . *at the Doric 6th. Avenue Motor Hotel, Seattle, Wash.*

Travelers staying at this new, luxurious 175 unit motor hotel enjoy the latest conveniences of electrical living. Even the rooms are heated electrically so each person may select the room temperature he prefers.

These modern services require large electrical capacity. As a result, the available fault current is approximately 70,000 amperes.

Safe protection against faults of this magnitude is assured by the BUSS Hi-Cap fuses installed in the main entrance service. These fuses have an interrupting rating of 200,000 amperes rms. symmetrical.

To maintain safe, modern protection throughout the electrical system,—and to safeguard against unnecessary interruptions in electrical service, FUSETRON dual-element fuses are installed in the branch circuit switches.

ANOTHER BUSS HI-CAP AND FUSETRON FUSE INSTALLATION

There is a safe, modern BUSS or FUSETRON fuse with specific characteristics to match your requirements.

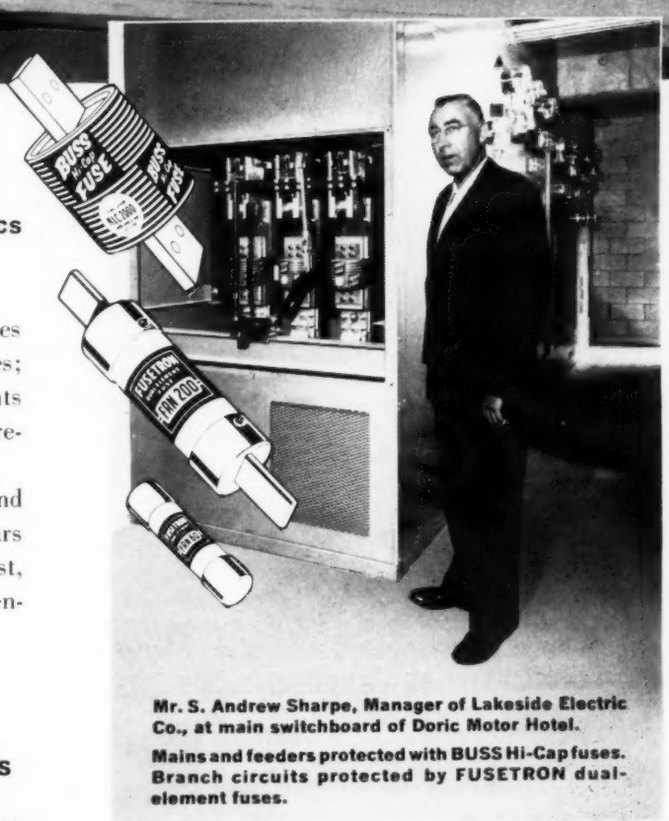
Available from BUSS: High interrupting capacity fuses to protect against fault currents up to 200,000 amperes; current-limiting fuses to restrict let-thru fault currents to safe values: long time-lag (dual-element) fuses to prevent needless outages on harmless overloads.

And with Fuses safe protection remains safe. BUSS and FUSETRON fuses are just as safe and accurate 20 years or longer after installation as on the day installed. Dust, fumes, corrosion or age cannot prevent them from opening when they should.

For more information on

FUSETRON dual-element fuses
(loads of 0 to 600 amps.) ..... **write for bulletin FIS**

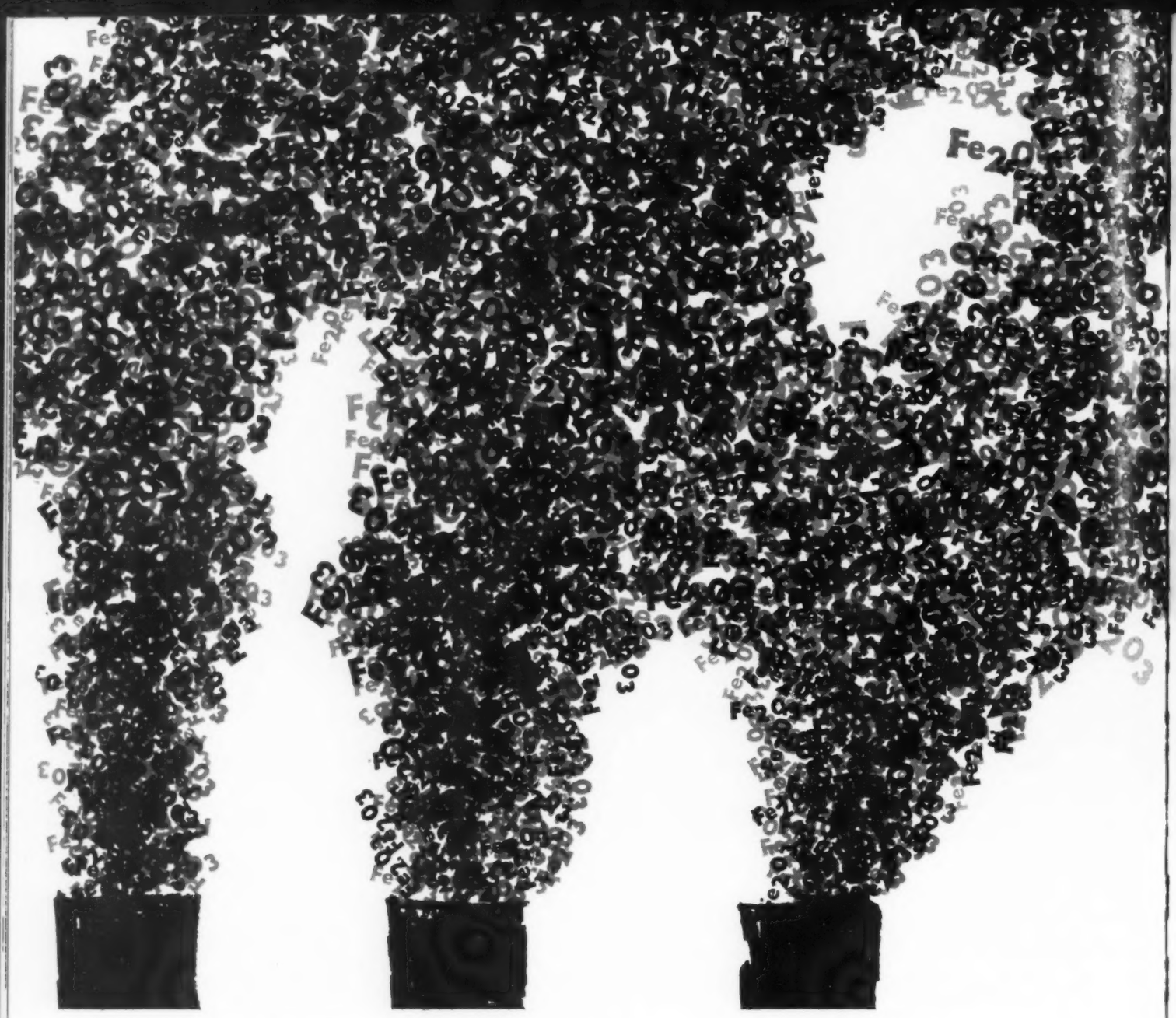
BUSS Hi-Cap fuses
(loads above 600 amps.) ..... **write for bulletin HCS**



Mr. S. Andrew Sharpe, Manager of Lakeside Electric Co., at main switchboard of Doric Motor Hotel.

Mains and feeders protected with BUSS Hi-Cap fuses. Branch circuits protected by FUSETRON dual-element fuses.

BUSSMANN MFG. DIVISION, *McGraw-Edison Co.*, **ST. LOUIS 7, MO.**



USING O_2 IN YOUR OPEN HEARTH? Chemico Venturi Scrubbers do more than simply solve the air polution problems brought on by the use of oxygen in steel making. Operating and performance figures indicate that for oxygen steel converters, oxygen lanced open hearth furnaces, electric furnaces and flame scarfing, the Chemico Venturi Scrubber solves those problems with higher efficiency and at lower cost than any other method now in operation. Specifically, these are the advantages of a Chemico Venturi Scrubbing System:

CAPITAL INVESTMENT—Chemico Venturi Scrubbers can be installed for approximately 30-50% less capital cost than required for electrostatic precipitators.

OPERATING AND MAINTENANCE COSTS—Chemico Venturi Scrubbers require so little maintenance and manpower, that over-all operating costs are dramatically lower than for other methods, even though power requirements may sometimes be slightly higher.

CONSISTENT PERFORMANCE—The Chemico Venturi Scrubber attains maximum cleaning efficiency at start-up. This peak efficiency is not decreased by subsequent changes in the gas flow or other variations in process conditions.

COLLECTION AND DISPOSAL—The Chemico Venturi Scrubber collects iron oxide dust wet and recovers it dry—free of contaminants and ready for re-use. It eliminates the common and very serious problem of how to handle and dispose of dry dust collected in an electrostatic precipitator.

WATER REQUIREMENTS—The Chemico closed cycle scrubbing process eliminates water disposal problems and cuts make-up water requirements to a minimum. Normally, no more than 50-100 GPM is needed.

PROCESS FLEXIBILITY—Adjustable Venturi throat permits automatic control of furnace draft while maintaining full cleaning efficiency.

If you are considering the installation of gas cleaning equipment, a Chemico representative would be pleased to discuss performance and cost figures with you. Chemico handles the complete job:

PLANNING—DESIGN—ENGINEERING—CONSTRUCTION and START-UP.

CHEMICO

Chemical Construction Corporation, Gas Scrubber Division, 320 Park Ave., New York 22, New York

Ferndale, Mich. Chicago, Ill. Los Angeles, Calif. Houston, Tex. Bartow, Fla. Birmingham, Ala. Pittsburgh, Pa.

Operator reads Speedomax H chart record

Hot ingot is pulled at Inland

New Trend in Soaking Pit Practice

Accelerated heating of Inland Steel's biggest ingots

Fast heating of giant 20-ton ingots, close temperature control and excellent scale deposition are some of the advantages that Inland Steel is getting from 6 batteries of 18 new Salem-Brosius soaking pits at Indiana Harbor Works.

These advantages are, in part, gained by new accelerated heating systems that feature the Speedomax® Type H temperature controller.

When cold ingots are charged, the pit operator sets a predetermined accelerated heating program by means of a timer on his central control panel. During the period of fast heating, extra fuel is supplied to the pits, driving pit temperature to an accelerated control point. This higher point is determined by metallurgical conditions and may be reset as conditions demand. As the ingot soaks up this extra heat, and the fast-heating period is completed, fuel is cut back and Speedomax H returns the pits to normal control temperature for the remainder of the soak period.

Because of this efficient control system, heat-up time is cut and the production of ingots is increased, assuring that the new rolling mills can operate at maximum output.

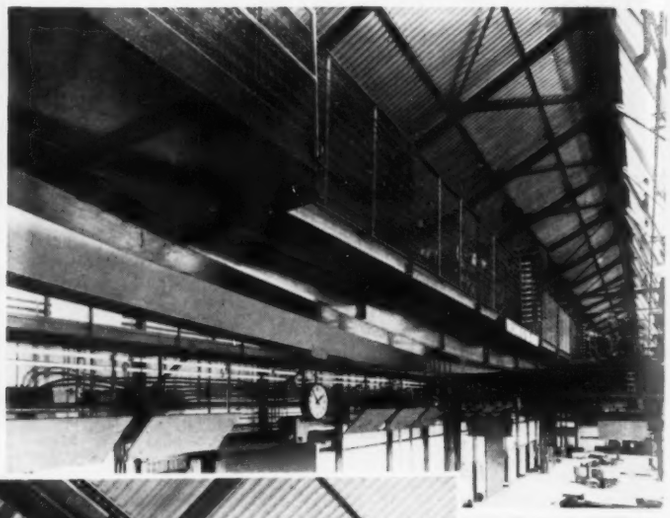
Because of their reliability, L&N temperature control instruments are specified by a majority of soaking pit users and manufacturers. So, when you modernize—or build soaking pits—ask your L&N Field Engineer to show you what L&N temperature controls . . . and our equally dependable combustion controls . . . can do for you. Or write to 4942 Stenton Avenue, Phila. 44, Pa.

LEEDS Instruments NORTHRUP Automatic Controls • Furnaces

Once again Henry Wiggin & Company Ltd. order

WELLMAN CRANES

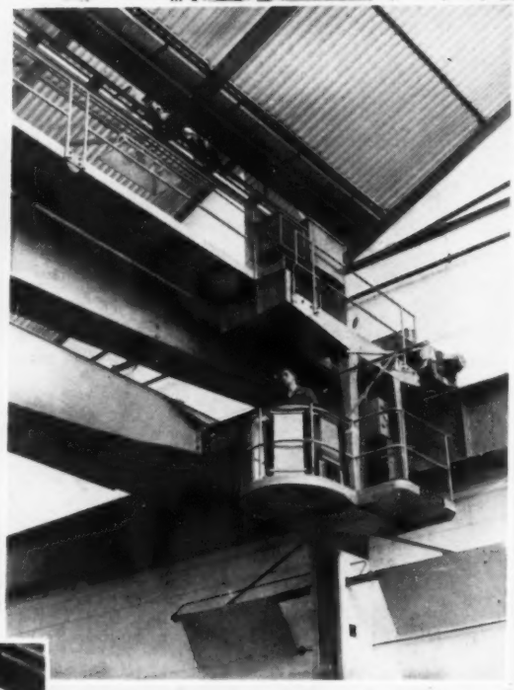
for their works at Hereford

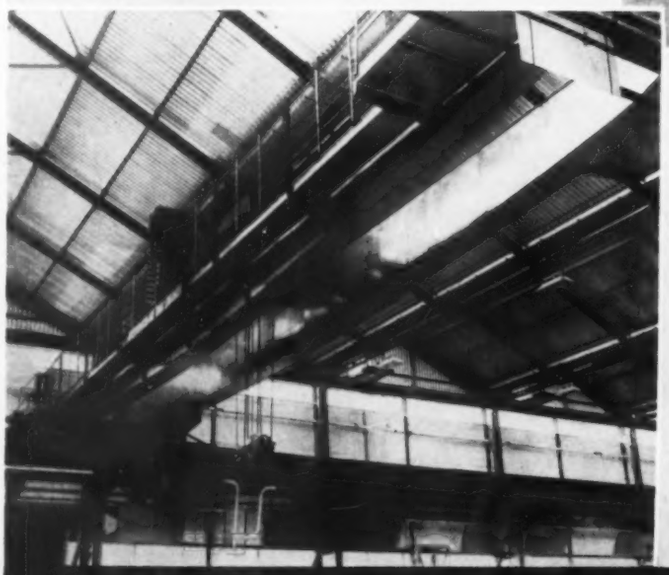


Henry Wiggin & Company Ltd., of Birmingham, Leading Nickel and Nickel Alloy Steel Manufacturers, continue to rely on Wellman Cranes.

Dependability, the hallmark of Wellman Cranes, is the very essence of continued full production.

First rate design team, three well-equipped manufacturing works, and complete shop erection before delivery to site, combined with many years of experience in both design and application, form the background of modern Wellman Cranes.





The photographs, by courtesy of Henry Wiggin & Company Ltd., show our latest box plate type girder resulting in low overall weight, high-speed travel and pleasing clean-cut design. The machine has a main hoist capacity of 15 tons, with auxiliary hoist capacity of 5 tons, has a span of 77 feet at a height of 25 feet above floor level.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LTD.
PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, South Staffs, & BELFAST.

56-inch semi-continuous hot strip mill.

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Blaw-Knox designs and builds a full range of continuous, semi-continuous and single stand reversing hot strip mills. Other Blaw-Knox equipment for the metals industry includes complete rolling mill installations and auxiliary equipment for ferrous and non-ferrous metals, sheet and strip processing equipment, electrolytic tinning, annealing and galvanizing lines, seamless pipe and tube mills, draw benches, and cold draw equipment, Blaw-Knox Medart cold finishing equipment, iron, alloy iron and steel rolls, carbon and alloy steel castings, fabricated steel plate or cast-weld design weldments, steel plant equipment, and heat and corrosion resisting alloy castings. Blaw-Knox Company, Foundry and Mill Machinery Division, Blaw-Knox Building, 300 Sixth Avenue, Pittsburgh 22, Pennsylvania.

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms • Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes • Towers and Special Structures • POWER: Power Plant Specialties and Valves

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QUITE A FEW OF
YOUR COMPETITORS
ARE DESCALING THEIR
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AND PIPE AT A
LOWER COST
THAN YOU ARE . . .
SIMPLY BECAUSE
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METAL BLAST's

"SUPER-STEEL"

SHOT and/or GRIT! *

HERE'S WHY THEY CHANGED . . .

They're paying only $165.00 per ton (truck loads) — considerably less than you are, if you're using competitive steel abrasives. Yet, SUPER-STEEL gives them excellent cleaning, greater resistance to breakdown and lower maintenance costs. Why don't you, too, take advatage of this opportunity to cut costs? We'll rush a trial order, lab test samples, full information or have our sales engineer call.

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MANUFACTURERS ALSO OF TOP QUALITY "SEMI-STEEL" SHOT AND GRIT, MALLEABLE AND CHILLED SHOT AND GRIT — AT COMPARABLE SAVINGS!

Date-line Diary...

July 1

Δ The International Nickel Co. of Canada, Ltd. increased the export price from Canada to the U. S. of electrolytic refined nickel 7¼¢ to 81¼¢ per lb (U. S. currency); the new base price for refined nickel in Europe is £660, an increase of £60 per long ton, applicable to nickel produced either at Canadian or British refineries.

Δ The AISI reports that production of steel for the week ending July 1, 1961, totaled 1,925,000 net tons (about 67.4 per cent of capacity) compared with 1,978,000 tons one week ago (69.3 per cent of capacity) and 1,510,000 tons one year ago. Index of production was 103.3.

July 3

Δ Copper price in London dropped ½¢ to 28⅝¢ a lb; copper future contracts in New York dropped 0.39¢ to 0.64¢ to prices ranging from 29.85¢ to 30.07¢ per lb.

Δ The Bureau of the Census reports that shipments of iron and steel castings in April, 1961, totaled 1,018,801 tons compared with 1,022,230 tons in March, 1961 and 1,250,190 tons in April, 1960.

Δ American Iron Ore Assn. reported that shipments down the Great Lakes in June, 1961, totaled 8,786,746 gross tons, compared with 12,027,467 tons in June, 1960.

July 5

Δ The Federal Reserve Board reported that consumers debt in May, 1961, increased $27,000,000, compared with a $139,000,000 reduction in April, 1961. The debt showed a decline of $375,000,000 from the January 1, 1961 total, but was more than $1,000,000,000 higher than the May 31, 1960 level.

Δ The AISI reports that the steel industry's payroll for hourly and salaried workers in May, 1961, totaled $326,162,209 compared with $291,967,656 in April, 1961. Total employed in May numbered 518,641 compared with 501,323 in April. Payroll cost per hr worked by hourly employees was $3.467 in May compared with $3.500 in April not including 47.1¢ per hr supplemental employee benefits. Average hours worked per week were 38.3 in May, 1961, compared with 35.7 in April, 1961.

July 6

Δ The Bureau of Mines reports that production of Pennsylvania anthracite in June, 1961, totaled 1,373,000 net tons, compared with 1,447,000 tons in May, 1961 and 1,496,000 tons in June, 1960.

Δ The Labor Dept. reported that employment in the month ended June 15, 1961, showed an increase of 1,928,000 over mid-May, totaling 68,706,000. Unemployment in the same period rose 812,000 to a total of 5,580,000, reflecting the entrance of teenagers into the summer labor market.

Δ Spot tin advanced 1¾¢ to $1.16 a lb on the London Metal Exchange.

July 8

Δ The AISI reported that steel production for the week ending July 8, 1961, totaled 1,779,000 net tons (about 62.1 per cent of capacity) compared with 1,925,000 tons one week ago (67.4 per cent of capacity) and 1,203,000 tons one year ago. Index of production was 95.5.

July 10

Δ Dealers sales of new U. S.-made automobiles in June, 1961, totaled 538,750, slightly below May, 1961 and 9.3 per cent below June, 1960.

Δ The Bureau of Mines reported that April, 1961, shipments of steel mill products totaled 5,100,000 tons compared with 5,000,000 tons in March, 1961. Imports of steel mill products in 1961 to May 1, 1961, totaled 743,000 tons and export totaled 585,000 tons.

July 11

Δ The Bureau of Mines reports that consumption of scrap in May, 1961, totaled 5,330,000 gross tons, compared with 4,665,842 tons in April, 1961; pig iron consumption in May, 1961, totaled 5,234,000 gross tons, compared with 4,320,346 tons in April, 1961.

Δ The Bureau of Statistics reports that Canadian steel production in June, 1961, totaled 555,638 tons, compared with 434,070 tons in June, 1960; pig iron output in June, 1961, totaled 419,194 tons, compared with 335,532 tons in June, 1960. For the first six months of 1961 steel production totaled 3,124,265 tons, compared with 3,120,760 tons in 1960; pig iron production totaled 2,294,165 tons compared with 2,274,763 tons in the first half of 1960.

Δ The Government reported that retail sales in June, 1961, rose to a seasonally adjusted figure of nearly $18,300,000,000, an increase of one per cent over the May level.

Δ The Bureau of the Census reported that shipments of commercial steel forgings in May, 1961, totaled 105,726 tons compared with 95,641 tons in April, 1961, and 110,326 tons in May, 1960.

July 12

Δ The Labor Dept. reported that employment rose sharply in nonfarm lines in the month ending June 15, 1961. Factory employment totaled 16,000,000, up 240,000 from mid-May; weekly earnings of these workers reached a record $94.24, up $1.34 per week from mid-May and $2.64 greater than on June 15, 1960.

Δ USW and Lone Star Steel Co. approved a new 4-year contract effective to September 7, 1965.

July 14

Δ The Bureau of the Census reports that net shipments of aluminum pig and ingot in May, 1961, totaled 129,923,000 lb compared with 92,530,000 lb in April, 1961, and 124,198,000 lb in May, 1960; net shipments of aluminum mill products in May, 1961, totaled 294,912,000 lb, compared with 268,647,000 lb in April, 1961, and 271,426,000 lb in May, 1960. Net shipments of magnesium mill products in May, 1961, totaled 1,815,000 lb compared with 1,341,000 lb in April, 1961, and 1,989,000 lb in May, 1960.

Δ The Bureau of the Census reported that shipments of titanium mill products in May, 1961, totaled 555,608 lb compared to 746,548 lb in April, 1961, and 810,464 lb in May, 1960.

July 15

Δ The AISI reported that steel production for the week ending July 15, 1961, totaled 1,860,000 net tons (about 65.2 per cent of capacity) compared with 1,779,000 tons one week ago (62.1 per cent of capacity) and 1,476,000 tons one year ago. Index of production was 99.8.

July 17

Δ Crude steel output in Germany in the first five months of 1961, totaled 14,410,422 tons, compared with 14,053,707 tons in the same period of 1960; crude iron production in the 1961 period totaled 10,777,565 tons, compared with 10,651,903 tons in the 1960 period. Rolled steel output in the 1961 period totaled 9,425,202 tons against 9,363,508 tons in the first five months of 1960.

Δ Westinghouse Electric Co. reported sales for the first half of 1961, totaling $920,381,000, net earnings of $19,561,000, equal to 54¢ a share, compared with sales of $953,844,000, net earnings of $40,454,000, equal to $1.44 a share in the first half of 1960.

July 18

Δ Can Manufacturers Institute, Inc. reports that canmakers consumed 415,726 tons of steel in May, 1961; shipments of aluminum cans totaled 3705 tons in this period.

July 19

Δ The ARCI reported that deliveries of new freight cars in June, 1961, totaled 3142 compared with 3360 in May, 1961 and 6042 in June, 1960. Orders in June, 1961, totaled 1214 compared with 3666 in May, 1961, and 321 in June, 1960. Backlog of cars on order as of July 1, 1961, totaled 11,821 compared with 13,964 as of June 1, 1961 and 29,555 on July 1, 1960.

July 20

Δ President Kennedy reported that the nation's production of goods and services in the second quarter of 1961 reached a record annual rate of $515,000,000,000, up $14,000,000,000 from the first quarter pace.

Δ The Census Bureau reported that home building in June rose to a seasonally adjusted annual rate of 1,374,000 units, six per cent over the May, 1961 rate and seven per cent above the June, 1960 rate.

July 21

Δ The AISI reports that blast furnace production in June, 1961, totaled 5,730,198 net tons, compared with 5,693,628 tons in May, 1961.

Δ A Federal deficit of $3,900,000,000 was formally reported for the fiscal year ended June 30, 1961.

July 22

Δ The AISI reported that steel production for the week ending July 22, 1961, totaled 1,858,000 net tons (about 65.0 per cent of capacity) compared with 1,860,000 tons one week ago (65.2 per cent of capacity) and 1,550,000 tons one year ago. Index of production was 99.7.

July 24

Δ The Aluminum Assn. reports that primary aluminum production in June, 1961, totaled 159,092 tons, compared with 157,544 tons in May, 1961 and 171,356 tons in June, 1960. Shipments in the first half of 1961 totaled 913,282 tons compared with 1,007,353 in the like 1960 period.

July 25

Δ The AISC reported that shipments of fabricated structural steel in June, 1961, totaled 361,159 tons compared with 364,996 tons in May, 1961, and 374,231 tons in June, 1960. Bookings in June, 1961, totaled 297,555 tons compared with 391,703 tons in May, 1961, and 299,596 tons in June, 1960. Backlog as of June 30, 1961, totaled 2,414,684 tons. Shipments for the first half of 1961, totaled 1,858,960 tons, compared with 1,834,645 tons in the like 1960 period; bookings in the first half of 1961, totaled 1,858,825 tons, compared with 1,940,982 in the same period of 1960.

July 26

Δ Japan produced 13,225,000 tons of iron and steel in the first six months of 1961, 26 per cent over its output in the first half of 1960.

Δ The Bureau of the Census reports that shipments of nonferrous castings in May, 1961, totaled 182,022,000 lb, compared with 166,702,000 lb in April, 1961

Δ Allegheny Ludlum Steel Corp. has withdrawn from the Steel Industry Co-ordinating Committee which spearheaded the industry's contract negotiations with USW in 1959.

Δ United Engineering and Foundry Co. reported sales for the first half of 1961, totaling $40,769,595, net income of $2,617,538, equal to $1.02 a share, compared with 1960 first half sales of $33,522,698, net income of $2,432,595, equal to $0.95 per share.

Δ The Labor Dept. reported that consumer prices rose 0.2 per cent in June, 1961 to 127.6 per cent of the 1947–49 average.

July 27

Δ The National Machine Tool Builders Assn. reports that net new orders of cutting and forming type machine tools in June, 1961, amounted to $60,600,000, compared with $49,600,000 in May, 1961. Shipments of cutting and forming type tools amounted to $64,300,000 compared with $57,900,000 in May, 1961.

July 28

Δ The Commerce Dept.'s mid-year outlook report on the iron and steel industry predicts production of 55,000,000 tons of steel ingots in the last half of 1961 compared with 45,000,000 tons in the first half.

July 29

Δ The AISI reported that steel production for the week ending July 29, 1961, totaled 1,818,000 net tons (about 63.5 per cent of capacity) compared with 1,858,000 tons one week ago (65.0 per cent of capacity) and 1,520,000 tons one year ago. Index of production was 97.6.

July 31

Δ The Commerce Dept. reported that manufacturers' bookings in June, 1961, totaled $31,000,000,000 after seasonal adjustment, down $50,000,000 from the May, 1961 level. Manufacturers' inventories were stable in June, 1961, for the third consecutive month, contrasting with a $400,000,000 cutback in the first quarter of 1961.

Δ The Commerce Dept. reported that construction outlays for July, 1961, on a seasonally adjusted pace, amounted to $58,700,000,000 annually, up two per cent from the June, 1961 level, and five per cent higher than the July, 1960 rate.

Δ The Japan Iron & Steel Federation reports that Japan produced in May, 1961, 1,474,000 net tons of pig iron and 2,645,000 tons of crude steel.

Δ American Iron Ore Assn. and AISI joint report shows receipts of iron ore in the U. S. in June, 1961, totaled 11,301,667 gross tons compared with 16,292,641 tons in June, 1960. Iron ore consumption in June, 1961, totaled 8,544,967 gross tons compared with 8,059,541 tons in June, 1960. Blast furnaces operating as of June 30, 1961, totaled 145 of the existing 255. On June 30, 1960, 151 blast furnaces were operating.

Δ F. W. Dodge Corp. reports that construction contracts in June, 1961, amounted to $3,602,176,000 compared to $3,472,276,000 in June, 1960; for the first six months of 1961 contracts totaled $18,219,696,000, compared with $17,573,828,000 in the same period, 1960, June, 1961 index (1947–1949 = 100 per cent) was 281, compared with 257 in May, 1961 and 272 in June, 1960.

STEEL COMPANIES QUARTERLY FINANCIAL REPORTS—JUNE 30, 1961

	Period	1961 Net Sales	1961 Net Profits	1961 Earnings per share	1960 Net Sales	1960 Net Profits	1960 Earnings per share
Acme Steel Co.	2nd quar.	$ 34,790,399	$ 372,806	$ 0.07	$ 35,774,772	$ 528,394	$ 0.15
	1st half	65,454,147	400,171	0.02	82,626,119	2,620,916	0.87
Alan Wood Steel Co.	2nd quar.	14,376,000	152,000	0.13	16,763,000	350,000	0.42
	1st half	27,640,000	(74,000)*	(0.28)	36,968,000	1,205,000	1.56
Allegheny Ludlum Steel Corp.	2nd quar.	60,856,697	2,860,892	0.73	55,725,943	741,000	0.19
	1st half	115,042,240	4,293,120	1.10	135,398,561	5,532,584	1.43
Armco Steel Corp.	2nd quar.	226,372,912	13,915,522	0.94	246,872,807	17,775,225	1.20
	1st half	413,944,419	23,176,168	1.57	521,181,381	41,733,219	2.82
Atlas Steels, Ltd.	2nd quar.	13,285,000	593,000	...	12,709,000	625,000	...
	1st half	27,819,000	1,656,000	...	26,675,000	1,628,000	...
Bethlehem Steel Co.	2nd quar.	516,287,170	25,996,185	0.53	569,031,374	29,714,308	0.62
	1st half	949,737,241	33,967,877	0.67	1,224,852,388	81,543,035	1.72
Ceco Steel Products	2nd quar.	...	744,169	0.74	...	405,408	0.40
	1st half	...	969,736	0.97	...	523,332	0.52
The Colorado Fuel and Iron Corp.	2nd quar.	...	1,856,605	0.45	...	(432,260)	(0.14)
	1st half	...	367,585	0.04	...	2,414,432	0.56
Continental Steel Corp.	2nd quar.	15,043,160	1,398,000	1.36	12,692,218	1,032,802	1.14
	1st half	26,432,590	2,286,059	2.21	25,910,482	2,308,642	2.24
Copperweld Steel Co.	2nd quar.	28,448,881	495,844	0.42	32,803,302	864,344	0.74
	1st half	50,992,761	400,783	0.34	68,943,844	2,253,518	1.92
Crucible Steel Co. of America	2nd quar.	48,317,000	149,000	0.005	53,034,433	309,345	0.05
	1st half	88,708,000	(1,495,000)	(0.46)	124,668,352	3,034,143	0.72
Detroit Steel Corp.	2nd quar.	20,276,751	418,086	0.11	21,132,118	667,858	0.16
	1st half	36,264,858	299,918	0.08	55,804,036	4,207,465	1.06
Eastern Stainless Steel Corp.	2nd quar.	16,198,240	728,806	0.50	16,368,380	446,331	0.31
	1st half	31,229,556	1,202,709	0.83	34,798,891	1,225,666	0.85
Edgewater Steel Co.	2nd quar.	4,135,726	161,267	0.86	3,854,520	121,644	0.65
	1st half	7,806,813	227,296	1.21	8,434,224	284,908	1.52
Firth Sterling, Inc.	3rd quar.	6,016,200	14,100	...	5,990,300	(47,600)	...
	9 mos.	16,119,500	(281,800)	...	18,082,700	(208,400)	...
Granite City Steel Co.	2nd quar.	35,300,340	2,627,530	0.61	38,065,385	3,330,896	0.77
	1st half	66,424,624	4,537,805	1.05	81,489,041	7,644,551	1.77
Inland Steel Co.	2nd quar.	190,337,672	13,605,988	0.77	204,524,153	14,323,569	0.82
	1st half	351,285,405	21,749,580	1.23	432,089,962	33,067,503	1.89
Interlake Iron Corp.	1st half	37,926,792	1,425,405	0.03	51,836,476	3,467,140	1.54
Jessop Steel Co.	1st half	15,438,982	264,945	0.39	18,411,879	741,262	1.15
① Green River Steel Corp.	1st half	6,438,897	(58,999)	0.09	7,353,722	298,514	0.46
Jones & Laughlin Steel Corp.	2nd quar.	188,399,000	9,240,000	1.13	207,164,000	8,342,000	1.02
	1st half	346,505,000	11,827,000	1.41	461,588,000	26,136,000	3.24
Kaiser Steel Co.	2nd quar.	75,634,099	6,269,686	1.67	53,674,847	188,264	(0.19)**
	1st half	131,947,313	5,206,245	1.10	118,661,952	6,874,924	1.60
Keystone Steel & Wire Co.	Year	102,747,240	5,143,590	2.74	128,840,899	8,320,490	4.44
Latrobe Steel Co.	1st half	12,842,575	395,528	0.35	14,140,857	937,072	0.83
Lone Star Steel Co.	1st half	31,154,552	1,280,920	0.33	31,642,712	3,608,631	0.92
Lukens Steel Co.	12 wks.	24,788,000	1,378,000	1.44	24,312,000	963,000	1.01
	24 wks.**	46,943,466	1,918,640	2.01	54,729,261	3,276,907	3.44
McLouth Steel Corp.	2nd quar.	51,103,259	4,991,476	1.38	53,970,753	3,848,333	1.04
	1st half	91,090,430	7,167,451	1.96	117,291,200	9,675,307	2.64
National Steel Corp.	2nd quar.	167,225,289	10,302,140	1.35	174,406,640	9,583,019	1.26
	1st half	304,005,797	16,164,166	2.12	394,248,812	27,301,361	3.61
Phoenix Steel Corp.	1st half	18,400,000	(2,178,000)	(2.01)	24,800,000	(159,000)	(0.15)
Pittsburgh Coke and Chemical Co.	2nd quar.	12,560,000	(146,000)	(0.22)	18,696,000	455,000	0.31
	1st half	22,885,000	(646,000)	(0.68)	39,670,000	1,115,000	0.78
Pittsburgh Steel Co.	2nd quar.	32,537,435	(208,285)	(0.34)	37,229,628	237,617	(0.06)†
	1st half	58,424,396	(1,455,241)	(1.33)	87,853,474	2,405,194	1.10
Republic Steel Corp.	2nd quar.	259,722,347	15,431,357	0.98	267,856,117	13,168,938	0.84
	1st half	456,481,552	21,253,878	1.35	643,434,319	41,408,483	2.64
Sharon Steel Corp.	2nd quar.	25,489,855	289,124	0.26	25,137,240	65,364	0.06
	1st half	46,063,579	(261,639)	(0.24)	72,395,415	1,954,856	1.77
Steel Co. of Canada, Ltd.	2nd quar.	78,767,807	7,286,076	1.68††	73,267,948	5,679,220	1.31
	1st half	142,510,164	11,874,748	2.74††	156,229,225	13,876,345	3.20
United States Steel Corp.	2nd quar.	869,119,840	59,027,471	0.98	1,002,393,894	80,893,489	1.38
	1st half	1,577,832,547	91,004,141	1.45	2,189,948,509	193,472,241	3.35
Universal Cyclops Steel Corp.	2nd quar.	30,535,978	1,502,382	0.78	28,261,286	1,034,832	0.53
	1st half	55,274,598	2,100,440	1.09	64,561,420	3,120,826	1.61
Washington Steel Corp.	3rd quar.	...	207,783	0.31	...	392,008	0.59
	9 mos.	...	702,718	1.06	...	1,790,500	2.77
Wheeling Steel Corp.	2nd quar.	55,404,000	2,127,000	0.81	60,656,000	2,609,000	1.04
	1st half	100,374,000	1,717,000	0.42	137,778,000	8,156,000	3.47
Woodward Iron Corp.	2nd quar.	...	1,527,596	0.60	...	1,470,121	0.58
	1st half	...	2,474,971	0.97	...	2,682,167	1.05
Youngstown Sheet and Tube Co.	2nd quar.	146,010,330	8,163,845	2.34	152,377,231	5,997,762	1.72
	1st half	264,686,575	10,843,270	3.11	350,403,635	18,889,010	5.42

* Items in parentheses are losses.
** To June 17, 1961.
† After preferred dividends.
†† Based on 4,338,338 shares outstanding before rights issue, based on 5,061,394 shares outstanding after rights issue, earnings per share $1.44 for 2nd quar., $2.35 for first half.
① Wholly-owned subsidiary, earning's figured per share of Jessop Steel Co., consolidated earnings not shown.

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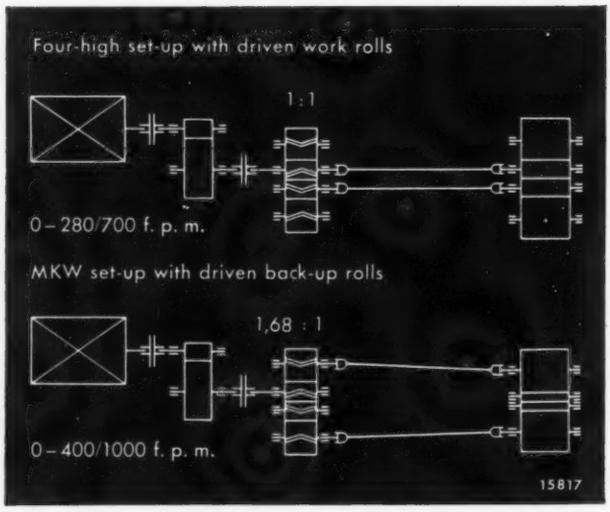

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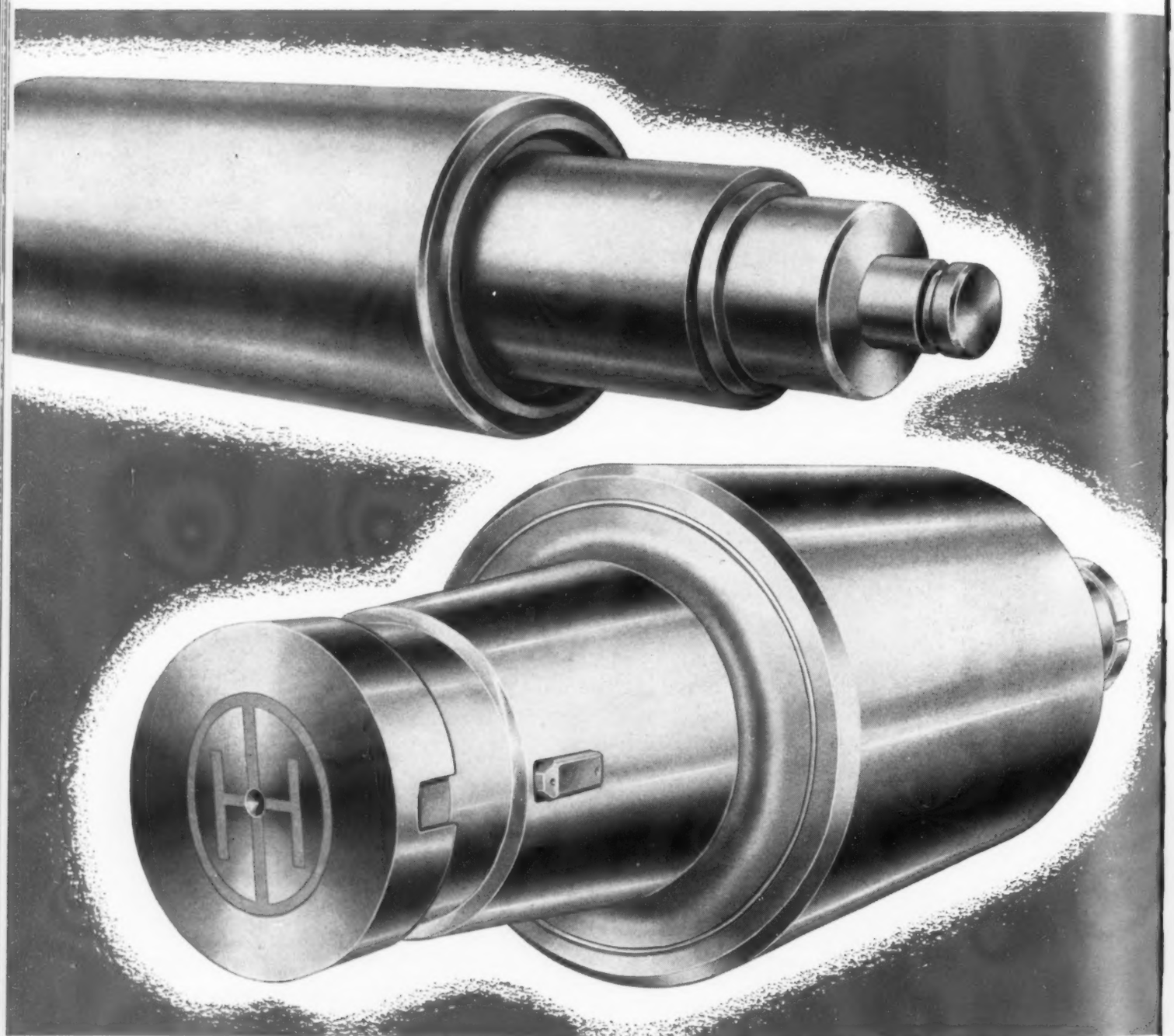

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OR-47

Industry News...

NATIONAL STEEL TO ADD FACILITIES AT WEIRTON FOR PRODUCTION OF LIGHTWEIGHT TIN PLATE

△ The first facilities especially designed and constructed for production of lightweight tin plate will be installed by National Steel Corp. at the Weirton, W. Va., plant of the Weirton Steel division, it was anounced by Thomas E. Millsop, chairman of National Steel.

The new facilities will consist of a two-stand tandem cold mill and a cleaning, chemical treating and oiling line. The tandem cold mill will be equipped with a total of approximately 7000 hp, and will be constructed for an operating speed of 3000 fpm.

Preparation of the site for two new buildings is already in progress, Mr. Millsop said. Contracts have been granted to Mesta Machine Co. for the tandem cold mill and to Wean Engineering Co. for the cleaning, chemical treating and oiling line. Initial operation is scheduled for early in the second half of 1962.

At Weirton Steel and other steel companies, Mr. Millsop pointed out, lightweight tin plate is now being produced on facilities that were originally built for other purposes and were modified to meet the production requirements of the new material. In Weirton's experience, he said, high quality standards have been maintained, but production volume has been limited because of the relatively slow operating speeds of the modified facilities.

Addition of the new facilities will increase Weirton Steel's capacity for production of lightweight tin plate by approximately 300 per cent. National Steel's capacity will be further increased by facilities at its new Midwest Steel division, in the Chicago area, which are scheduled for production later this year.

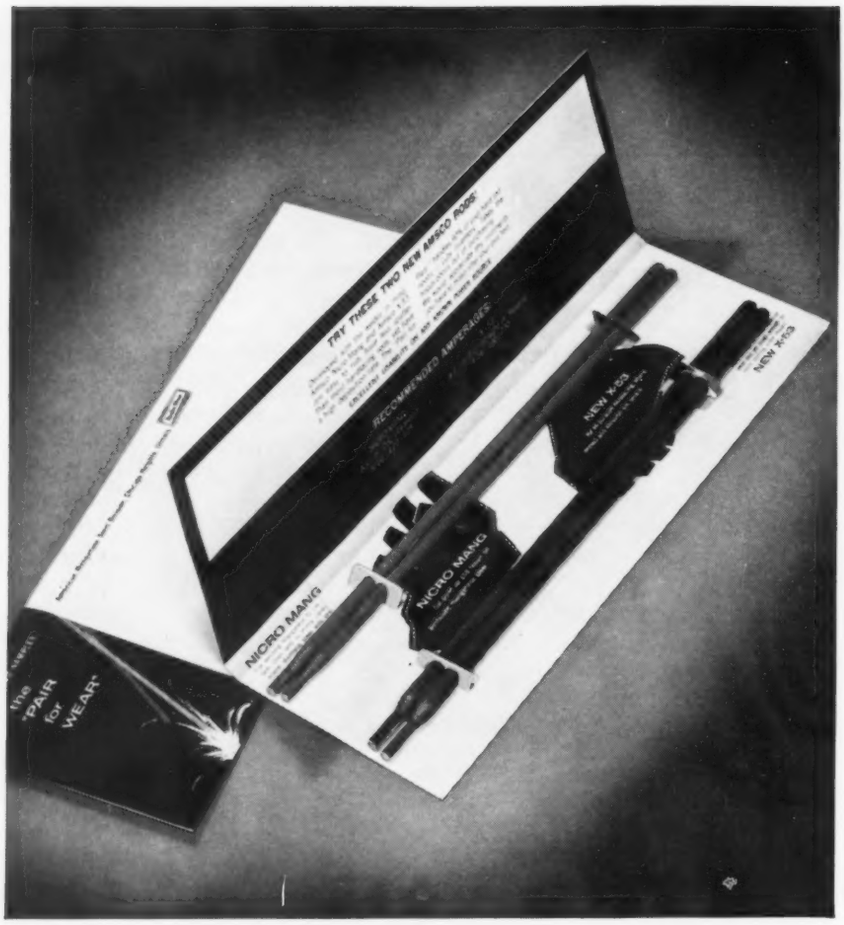
The addition to capacity is being made, Mr. Millsop stated, because of the enthusiastic acceptance of the lightweight material by customers and because of indications of steady and substantial growth of its use in the manufacture of containers. After lengthy experimental work in the mills, small quantities were produced for research and testing by can makers. Production was gradually increased to the point where it was regarded as on a commercial basis and Weirton Steel introduced its lightweight tin plate under the brand name "Weirlite" last December.

The lightweight material is first produced as conventional tin-plate coils. The coils are then cold rolled to reduce both the steel strip and its coating of tin to approximately one half of the original thickness and twice the original length. In further processing, the tin plate is cleaned, chemically treated, given a protective coating of oil and prepared for shipment to customers either in coils or sheets.

Because of the extra rolling operation required for its manufacture, lightweight tin plate has greater strength in proportion to thickness than conventional tin plate. Less steel is required to produce the thin material as compared with conventional tin plate and further econ-

FURNACE RAISED IN ONE DAY DURING REBUILD

When the William B. Pollock Co. enlarged and rebuilt the #1 Blast Furnace of Wheeling Steel Corp. at its Steubenville, Ohio, works, the existing furnace shell had to be raised six ft just above the mantle. Using a special designed jacking arrangement, riggers raised the furnace the required six ft in only 23 hr instead of almost a week required using previous methods. Furnace stayed plumb all the way up. External working space was more than ample.



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omies are realized because of weight savings in the shipment of both unfilled and filled containers.

The two new buildings at Weirton will have a combined floor area of approximately 45,000 sq ft and will be constructed as an extension of the tin mill. Tin plate will be conveyed directly from the four electrolytic plating lines to the new "Weirlite" plant. The material will flow in one direction through the tandem cold mill and in the opposite direction through the cleaning, chemical treating and oiling line to the present coil storage floor. Coils are moved from this area to adjacent facilities for cutting tin plate into sheets or bundling for shipment in coils.

WESTINGHOUSE TO EQUIP FRENCH HOT STRIP MILL

△ Westinghouse Electric International Co. and Le Materiel Electrique S-W, of Paris, jointly announced they will supply approximately $8,000,000 of electrical equipment to Union Siderurgique du Nord de la France, S.A. (Usinor) to power a new hot strip mill there.

R. L. Jeans, vice president—marketing of Westinghouse International, said the two companies will provide 12 main drive motors totaling 93,000 hp, main drive and auxiliary controls, 325 d-c table motors, switchgear, power centers and ventilating equipment.

Among the apparatus supplied by Westinghouse will be an advanced-design main drive motor to serve as prototype for main drives to be built by the French concern.

The Usinor mill will be capable of producing 80-in. strip at a speed of 3360 ft per min.

Production capacity of the mill will be 3,000,000 tons annually.

JAPANESE FIRM ORDERS WIDE FLANGE BEAM MILL

△ A new mill for rolling wide flange beams has been ordered from United Engineering and Foundry Co. by Fuji Iron and Steel Co.

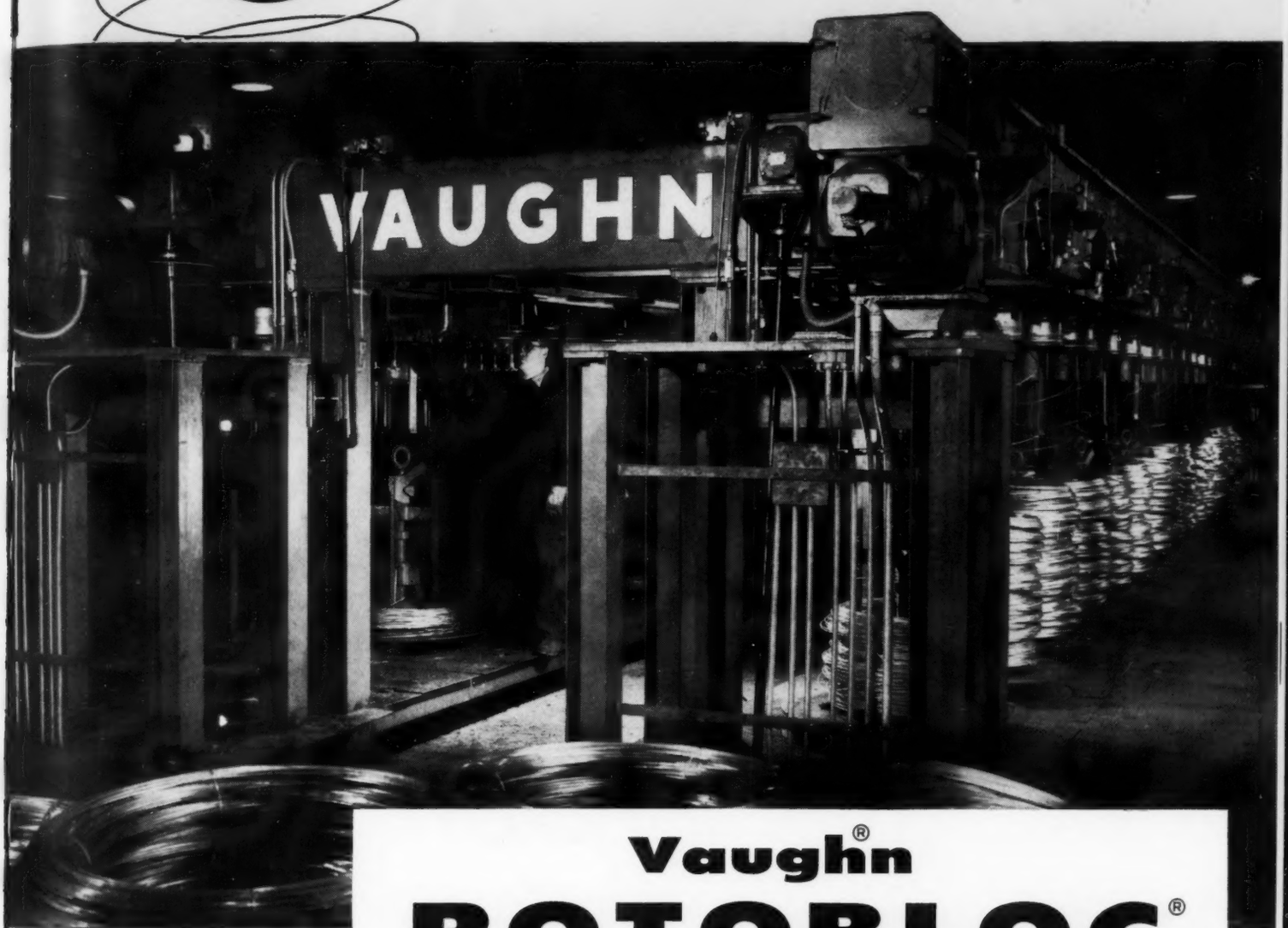
The new mill will produce wide flange beams up to 40-in. high as well as standard shapes.

Innovations in the design of the mill will bring about reduced roll costs, faster and semi-automatic roll changes and quick switchover from wide flange beam rolling to structural

Large bundle–non-stop operation

without twist!

FOR USS AT DONORA WORKS, AMERICAN STEEL AND WIRE DIVISION



Vaughn® ROTOBLOC®

GALVANIZING · ALUMINIZING · PATENTING

This impressive 32-block Rotobloc installation underscores the increasing acceptance of Vaughn non-stop bundle production by leaders of the wire industry. The Vaughn Rotobloc, operating at the end of your wire processing lines, assures uninterrupted flow that means better deliveries for the customer and lower costs in the mill. ● This machine may be built in any number of blocks, and can also be designed for drum payoff, if desired. Size range is from 16 gauge galvanized to 13/32" patented wire. For additional details, write.

THE VAUGHN MACHINERY COMPANY

CUYAHOGA FALLS, OHIO, U.S.A.

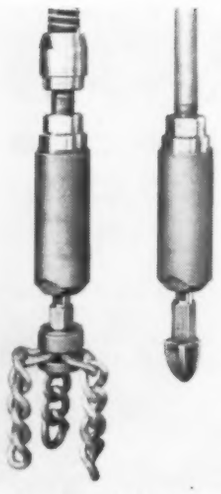
COMPLETE COLD DRAWING EQUIPMENT—Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys.

V®

CHECKERWORK cleaned faster, better with

ELLIOTT TUBE CLEANER

Substantial saving of time and labor, and thorough cleaning of passages without harm to brickwork are effected through the use of standard Elliott tube cleaner air motor with the special whirling chain head illustrated at the right. If stubborn deposits require drilling, the same motor can be equipped with an extension piece and drill. The photographs above show how effectively square corners are cleaned. Many steel mills report savings in manhours as high as 50 percent with use of the Elliott checkerwork cleaners. Write for complete details. YO-1



Motor with chain head (left) and with drill and extension piece

ELLIOTT COMPANY

GENERAL OFFICES: JEANNETTE, PENNSYLVANIA

PLANTS AT: Jeannette and Ridgway, Pa.; Springfield, Ohio

TURBINES · GENERATORS · MOTORS · COMPRESSORS · TURBOCHARGERS
EJECTORS · STRAINERS · TUBE CLEANERS

rolling. These improvements will result in lower operating costs and greater flexibility in finished products from the mill, which is expected to be completed and in operation late in 1962.

DEVELOP NEW TITANIUM PRODUCTION PROCESS

△ A new process for producing titanium briquettes of at least ninety per cent purity at significantly reduced costs has been developed by Micro Metals Corp.

The chemical-mechanical compression process eliminates the need for expensive titanium sponge (virgin titanium) used with titanium chips (scrap titanium) to produce titanium briquettes which are used in the production of titanium ingots. By using an all chip briquette, as opposed to a chip and sponge briquette which is three times as expensive, the over-all cost of an ingot may be reduced from five to fifty-five per cent depending on the purity specifications of the end user.

The reduced cost of producing titanium briquettes is expected to open new areas of application and to broaden its present use.

MIDWEST OPERATES HUGE GALVANIZING FURNACE

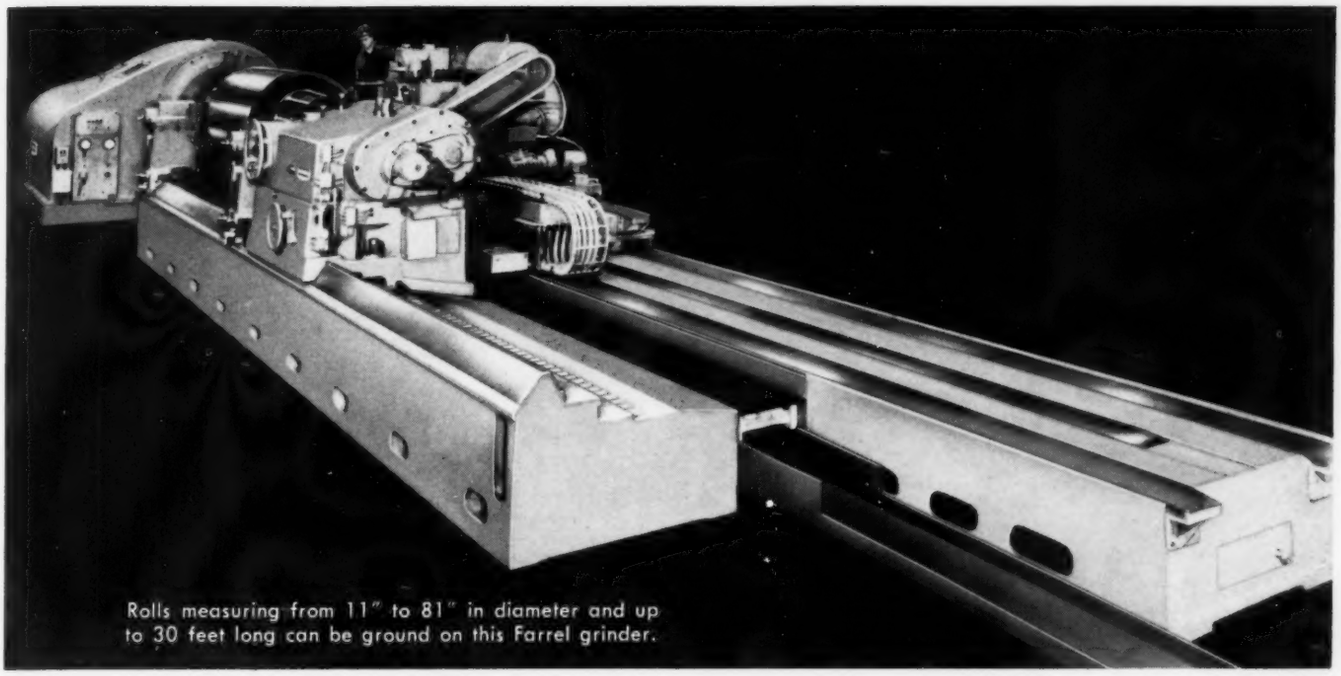
△ A huge galvanizing furnace that was completely factory bricked and shipped in sections convenient for final assembly is now in operation at the new plant of National Steel Corp.'s Midwest Steel Div.

The complete bricking of the furnace at General Electric's Industrial Heating Department is believed to be an industry first for a furnace of this type.

Comprising 175 ft of the 914-ft complete process line for producing galvanized steel strip, the furnace has a horizontal three-pass strip flow through the heating, holding and cooling sections. The strip leaves the furnace under protection of a hydrogen-nitrogen atmosphere and becomes coated by a quick dunk into a hot zinc bath.

General Electric personnel also handled the installation of the steel supporting structures and the joining and assembly of the furnace sections.

The Industrial Heating Depart-



Rolls measuring from 11" to 81" in diameter and up to 30 feet long can be ground on this Farrel grinder.

At United Engineering and Foundry...

LARGEST ROLL GRINDER

ever installed in the western hemisphere

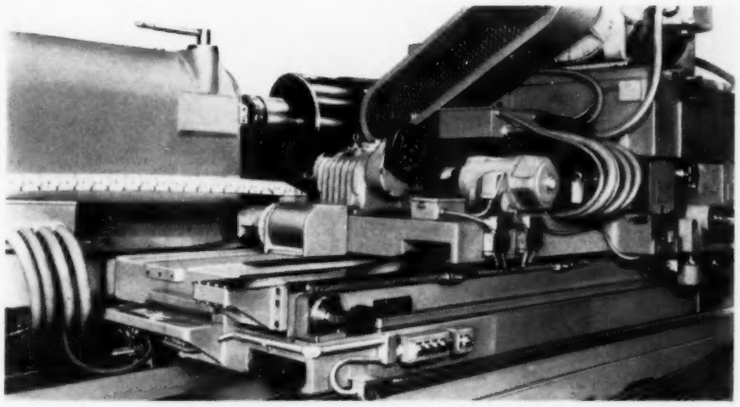
Built by Farrel to the requirements of United Engineering and Foundry Company, Pittsburgh, Pa., the machine above is now in service grinding mill rolls. It is the largest grinder ever built in this country and is capable of finishing the largest rolls used in the steel industry. It will handle rolls up to 81" diameter and will support 200 tons between centers.

As huge as it is, this is also one of the most accurate grinders ever built, thanks to Farrel's revolutionary new trunnion-tilt infeed system. And, because of the way the wheelhead is mounted on the upper part of a split carriage, it can be used with equal accuracy for grinding the roll face or taper journals. The upper carriage swivels and moves on its own ways in line with the angle of taper . . . can be operated in two directions for faster stock removal.

All controls are conveniently located on the operator's platform. From there, he can keep his eyes on the grinding wheel at all times.

This roll grinder is comprehensively covered in *new* 32-page bulletin 122.

Send for a copy today.



View of the special split carriage which permits grinding of taper journals using main wheelhead.

FARREL®

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
Sales Offices: Ansonia, Buffalo, Akron, Chicago, Los Angeles, Houston, Atlanta
European Office: Piazza della Republica 32, Milano, Italy

FB-1221

Lou Krakowski, General Superintendent of the Harrison Sheet Steel Company, is a guy who makes no bones about what he wants. It's service! And, for twenty years, he has been getting what he considers the best . . . Cities Service.

Turning out, among many other things, 125 steel desks a day, he wants complete and dependable lubrication service. One of the many Cities Service products he uses to get this job done is Trojan H-2 grease. For general greasing on all equipment, multi-purpose Trojan H grease has a wide range of application. And, because of the variety of jobs Trojan H grease does, it reduces his necessary lubrication stocks.

If you have to *get it on the line* . . . call your nearest Cities Service office . . . or write Cities Service Oil Company, 60 Wall Street. New York 5, N. Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

ment produced the atmosphere generating equipment which included three 20,000 CFH Neutralene H generators and two 4000 CFH Ammalene producers. General Electric also supplied the coordinated auxiliary equipment including a railroad tank car liquid ammonia supply and a pressure storage facility for Neutralene H.

LACKAWANNA TO ADD NEW GALVANIZING LINE

△ Construction of a multi-million dollar galvanizing line for the Lackawanna, N. Y., plant of Bethlehem Steel Co. is scheduled to begin about September 1.

The new production facility is expected to be in operation in about a year, and will be capable of turning out galvanized sheets up to 72-in. wide and coils up to 70,000 lb.

In addition, the line will produce sheets up to 8 gage (about 0.172-in. thick). It is believed it will be the only one able to manufacture so heavy a product. The line will have an average capacity of 200,000 tons per year. The building which will house the line will be 1000-ft long.

INSTALLS CONTINUOUS MERCHANT MILL AT GARY

△ United States Steel Corp. has installed a new 16-stand continuous merchant mill at its Gary, Ind., works, designed and built by Blaw-Knox Co. The mill rolls both carbon and alloy steels, in rounds from $\frac{3}{8}$ to $1\frac{1}{2}$ in., and various merchant shapes in equivalent sizes. The mill is comprised of eight vertical roll stands, eight horizontal roll stands, pouring reels, coil conveyor systems and other auxiliary equipment.

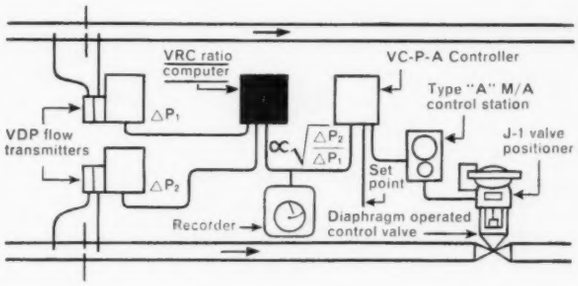
The finished merchant products are delivered from the mill either in coils weighing up to about 2000 lb or as cut-to-length product, from the cooling bed. The finished product of the mill is rolled from $2\frac{9}{16}$ in. to 5-in. sq billets and slab blooms up to 7-in. wide.

ENGLISH FIRM OPERATING UNIVERSAL BEAM MILL

△ Appleby-Frodingham Steel Co., Scunthorpe, England, has just put into production their new universal beam mill, engineered by Schloemann Aktiengesellschaft.

ROCKWELL-REPUBLIC

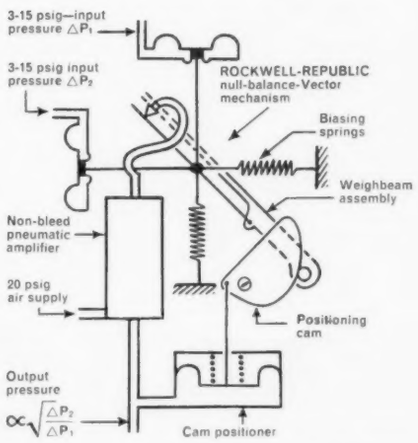
Ratios within 1% accuracy without square root extraction



This flow ratio control system is a typical application of a VRC Ratio Computer. Rockwell-Republic produces all components including orifice sections and control valves required for this system. You get the added value of one-source responsibility.

The new Rockwell-Republic VRC ratio computer replaces a conventional ratio device and two square root extracting mechanisms in the flow ratio pneumatic control system shown above. Flow ratio may be directly recorded. The VRC is the newest addition to the Rockwell-Republic family of Null-Balance Vector instruments. These compact, lightweight, 3 to 15 psig pneumatic control instruments include the VDP flow transmitters and the VC-P controller, also shown above. One basic principle is employed by the entire vector instrument line. Thus, spare parts inventories and training problems are simplified when these instruments are used together.

For more information about these and other Rockwell-Republic instruments and controls, just mail the coupon below. RF-25



This schematic of the VRC Ratio Computer shows how a cam controls position of the weighbeam and thereby controls the null-balance vector mechanism so that output pressure is proportional to the ratio of the two input pressures or the actual flow ratio. Shape of cam characterizes relationship of output pressure to ratio of input pressures.

REPUBLIC INSTRUMENTS AND CONTROLS
more fine products by
ROCKWELL

Please send latest literature on the following:

☐ VRC Ratio Computer ☐ Process Transmitters ☐ Controllers
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Republic Flow Meters Co. *(Subsidiary of Rockwell Manufacturing Company)*
2240 Diversey Parkway, Chicago 47, Illinois

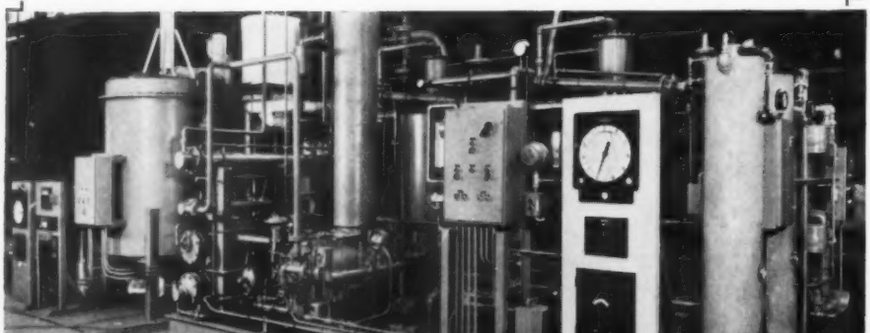
THE FANTASTIC FUTURE OF GAS ALLOYING

The potential of modern gas alloying is virtually limitless. Metallurgists are experimenting with chromium steels, soft-core abrasive-resistant steels, and low-alloy high-strength steels. Already in production:

BETTER ENAMELING STEELS, resulting from almost complete carbon removal, permit white goods manufacturers to get defect-free white or colored enamel products with a single enamel coat.

STRONGER TINPLATE, because of pinpoint control of carbon and nitrogen content. This also enables steel makers to make many grades of tinplate from a single grade of steel.

BETTER CARBON CONTROL for the production of better carbon steels. More uniform carbon distribution results in better carbon steel products. Non-aging rimmed steels are now possible, as are improved silicon steels.



Gas Atmospheres designed and built Packaged Hydrogen Generator.

PACKAGED GAS SYSTEMS for the production of hi-purity nitrogen, carbon and hydrogen gases have helped make this revolutionary new process possible. A pioneer and leading producer of packaged gas systems designed for gas alloying is *Gas Atmospheres, Inc., 3855 West 150th Street, Cleveland 11, Ohio.*

gas Atmospheres, inc 4130

GAS ALLOYING GAS ALLOYING GAS ALLOYING

THE IDEAL COUPLER
FOR INDUSTRIAL HAULAGE

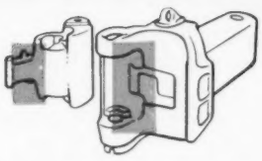
SHARON-10A

National's Sharon-10A Automatic Couplers are in use throughout the world on industrial cars, mine cars, railroad cars and transit cars. They can be furnished for varying service requirements such as regular top and bottom operation, improved type G side pull, type F side pull, rotary side or rotary bottom operation. For smaller cars not warranting use of the full-size Sharon-10A coupler, they can be furnished in 3/4 size as the Sharon-10 instead of with the full 10A contour.

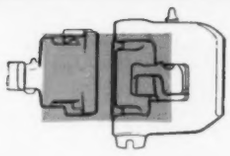
A-1285A

SHARON-10A • SHARON-10A • SHARON-10A

Gives longer service life. Liberal allowance for wear and distortion.



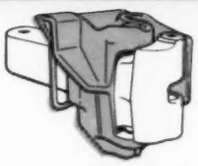
Has greater buffing strength. Substantial buffing shoulders in coupler head and knuckle.



Has less pulling stress. Lugs reduce stresses on knuckle pin.

SHARON-10A • SHARON-10A • SHARON-10A

Features secure locking. V-shaped design stabilizes lock in coupler wall.



Is protected from molten metal. Hood protects uncoupling mechanism from metal splash.

Is versatile. Can be supplied with slotted or off-set knuckle for use with present link and pin equipment.

GEARED TO PROGRESS P R I MEMBER

NATIONAL CASTINGS COMPANY

Established 1868

Transportation Products Division
Cleveland 6, Ohio

International Division Headquarters
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COUPLERS • YOKES • DRAFT GEARS • FREIGHT TRUCKS • JOURNAL BOXES
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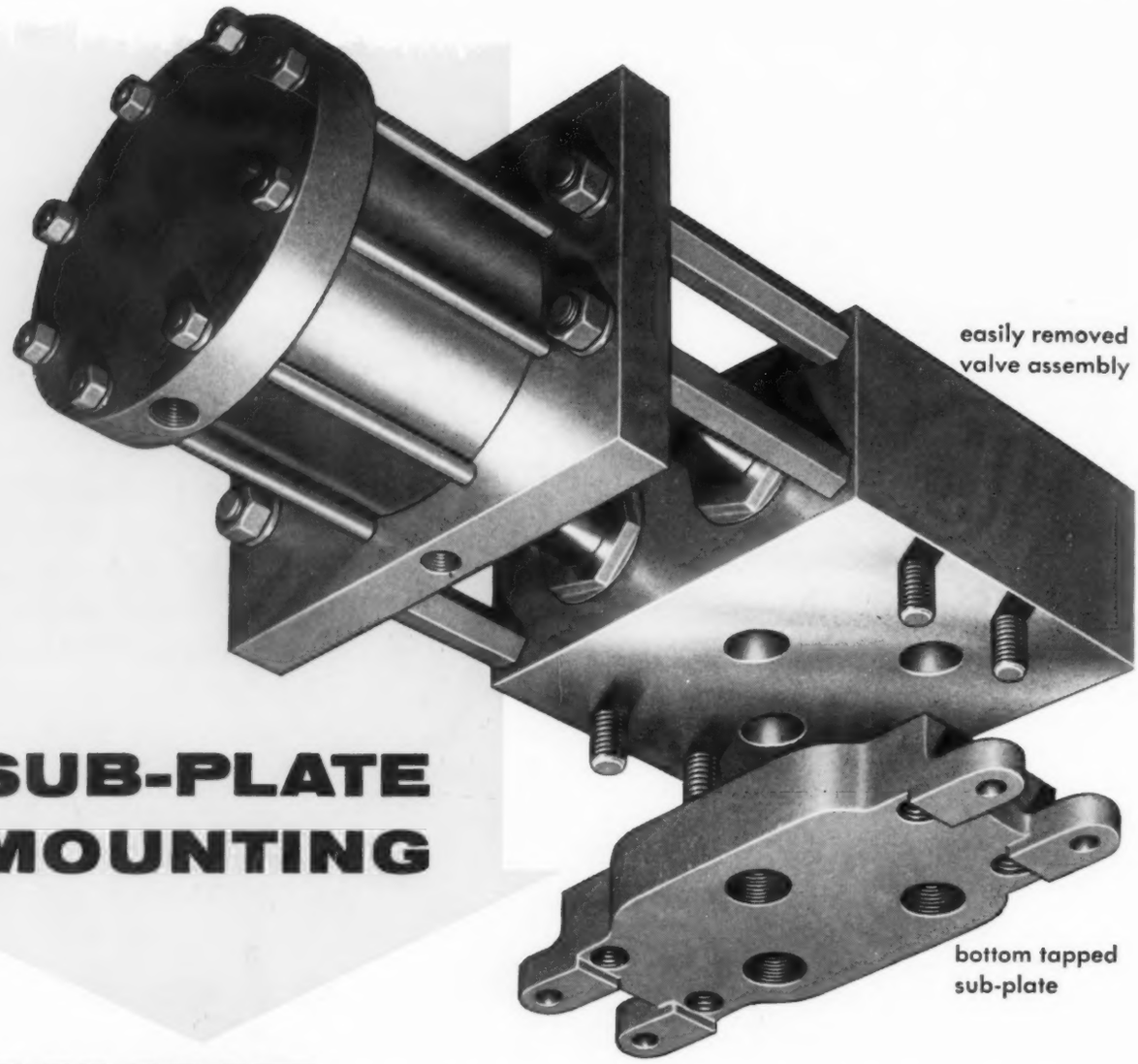


SUB-PLATE MOUNTING

for HUNT Hydraulic Valves

- ***easier maintenance***
- ***minimum downtime***

Designed to fit into today's preventive maintenance programs, Hunt's new sub-plate mounting permits quick valve removal and installation.

With sub-plates, equipment downtime is cut to an absolute minimum . . . valves can be repacked in your maintenance shop instead of on the machine. And, once installed, permanent piping need never be disturbed.

O-ring seals between valve body and cast steel sub-plate assure leak-free sealing . . . bottom tapping of sub-plate affords maximum access to valves and eliminates piping clutter.

Sub-plate mounting is available on all ½ through 2 in. Hunt hydraulic valves.* To learn more about the performance and cost-cutting advantages of Hunt valves, contact your nearby Hunt representative.

*Except those with cast or forged bodies.

HUNT

QUICK-AS-WINK® AIR AND HYDRAULIC

VALVES

HUNT VALVE COMPANY • DIVISION OF IBEC • SALEM, OHIO

Want more detailed information? Write Dept. ISE-861, Hunt Valve Company, Salem, Ohio. Ask for Bulletin 604.

3002

egg and crack it without crushing the egg.

It has the ability to provide stepless speed control from maximum speed down to zero from a single master switch.

General Electric engineers report this a-c reactor crane control is specifically designed for mill-duty applications defined by NEMA as Class V.

Application of the a-c reactor crane control system in the new Gary plate mill eliminates the need for d-c conversion equipment for cranes.

The use of static components helps reduce maintenance costs. The control for hoist drives utilizes static devices in both the primary and secondary circuits of a wound-rotor motor for speed control and torque reversal. Two saturable reactors and a saturable transformer are used in the primary circuit, and a fixed reactor and resistor are used in the motor secondary to perform these functions.

Crane drive motors are a-c mill type motors with d-c series brakes for hoist application and d-c shunt brakes for bridge and trolley applications.

CF&I TAPS FIRST HEAT FROM OXYGEN FURNACES

△ The first heat of steel has been tapped from Colorado Fuel & Iron Corp.'s new basic oxygen steel plant in Pueblo, Colo. The new installation, for which ground was broken on May 3, 1960, represents one of the major portions of the corporation's $21,000,000 modernization and expansion program.

A corollary to the oxygen steel plant is a $2,500,000 lime burning and lime storage facility which will be in operation the latter part of this year.

The new plant is capable of pouring out approximately 100 tons of molten metal every hour. One vessel will operate while the other is on standby or being relined.

Other improvements made in the Pueblo plant include an over-all expansion of all departments in the wire mills, a complete modernization of the 14-in. mill, the installation of a 69,000-kv loop transmission system to handle the extra power needs, plus technological improvements in the production of pig iron.

HOW TO BEAT THE HEAT

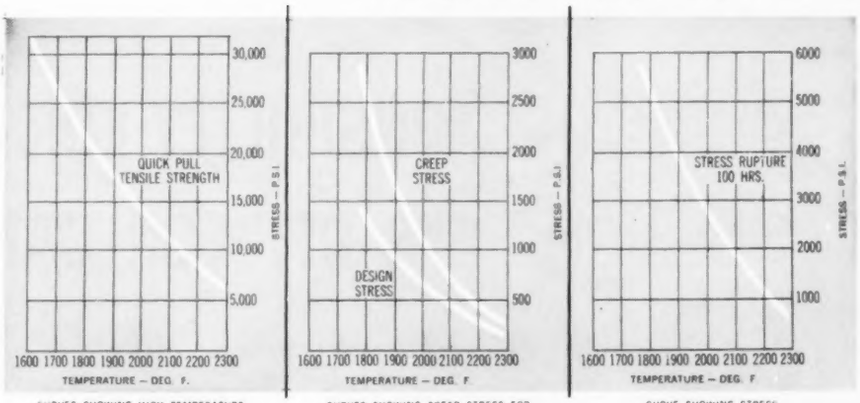
for strong high alloy requirements in the 1,800° to 2,300° F range!

DURALOY HOM*

*Covered by U.S. Patents

casting alloy

Duraloy "HOM" is a special high nickel alloy developed to produce castings that meet high temperature requirements, especially when castings are subject to oxidizing atmospheres.



CURVES SHOWING HIGH TEMPERATURE SHORT-TIME TENSILE STRENGTH OF DURALOY-HOM

CURVES SHOWING CREEP STRESS FOR CREEP RATE OF 1% IN 10,000 HOURS AND RECOMMENDED DESIGN STRESS FOR DURALOY-HOM

CURVE SHOWING STRESS TO RUPTURE AT 100 HOURS FOR DURALOY-HOM

Castings of DURALOY "HOM" are now being produced by our three methods: static, centrifugal and shell molded. Write today for additional information on this versatile new alloy.

ALLOY CASTING INSTITUTE ACI MEMBER

The DURALOY Company

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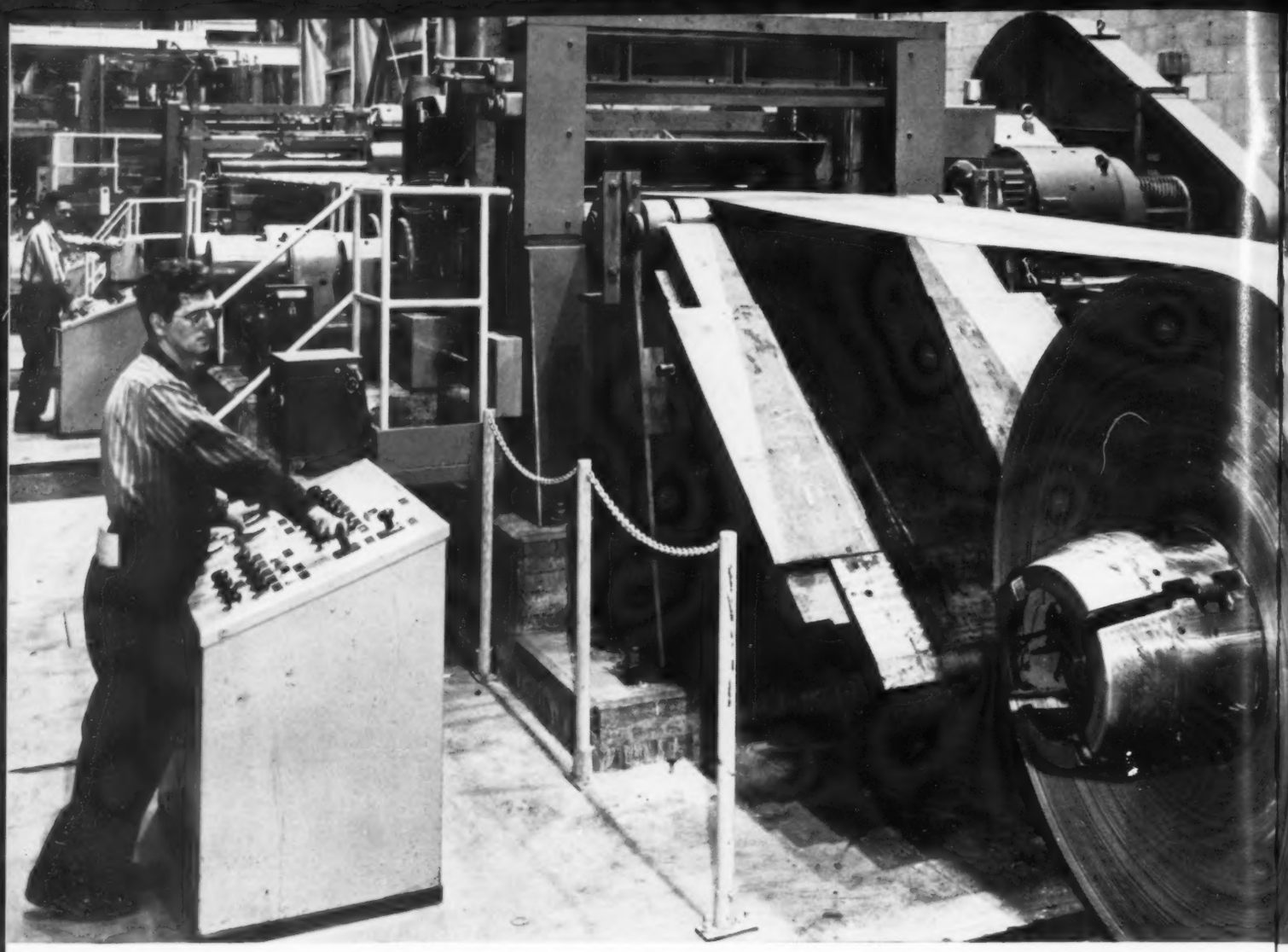


Feeding in strip at the entry reel of a galvanizing line in Hamilton, Ontario.

SINGLE RESPONSIBILITY FOR DRIVE SYSTEM DESIGN PAYS OFF FOR CANADIAN MILL

The motors, controls, regulators and sensing devices which drive this continuous galvanizing line were integrated to produce a precise performance by one totally responsible source . . . Reliance Systems Engineering.

The drive system was designed to utilize sectional generators and control, thus achieving more flexibility to handle a broader range of products. Any or all units of the line consequently can be changed to meet new production demands. Positive speed sychronization between sections is achieved with Reliance transistorized VSRR magnetic amplifier regulators.

Close control of the line is demonstrated by application of modern sensing devices. When light gauge strip is coiled, for example, a Reliance "Tensitron", senses, establishes and maintains tension at pre-set levels.

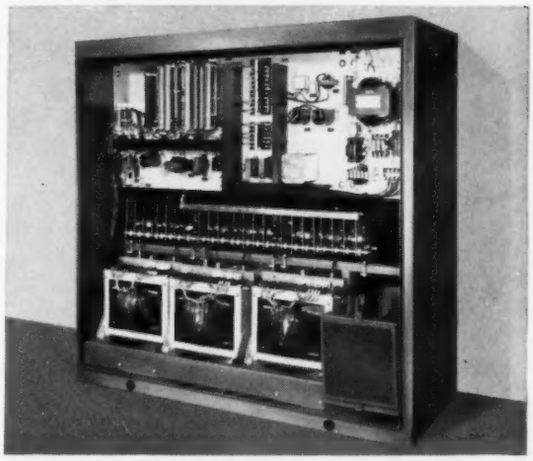
Precise tension and tracking of the strip was quickly created and preserved throughout all 32 sections of the line . . . and uniform, high quality strip was produced. Reliance willingly accepted *total responsibility* for the planning and engineering of this processing line drive at the request of the mill . . . with logical and practical results.

Reliance is ready and able to produce similar results for you. Your Reliance Systems Engineer can tell you even more about the advantages which can accrue to you through Reliance's Total Responsibility and Total Service. Call him —through your nearest Reliance office—or if you prefer, write us direct.

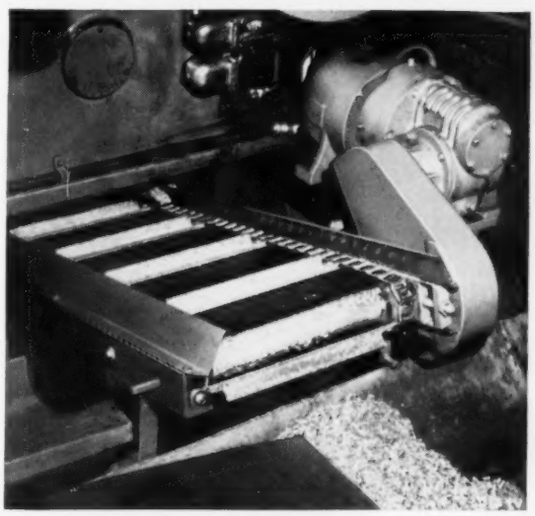
A-1687

RELIANCE...
builders of the tools of automation

NEW DUTY MASTER D-5000 design brings you new standards in coolness, quietness . . . and more horsepower in less space. Frame dimensions that held 150 hp. now contain 300 hp. There is better heat dissipation from the frame itself. Air flows easily through the entire grilled end areas—exhausts through long, protected slots at the sides and bottom. New fingerless ducted rotor design means better cooling than any other previous motor. You get all famous Duty Master features in this new D-5000 . . . special lubrication design, drip or splash-proof and complete open motor protection. Bulletin B-2515.

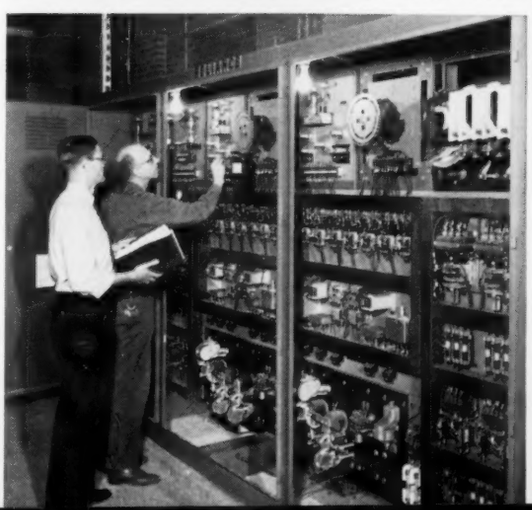


RELIANCE V★S STATATRON is a static powered drive for wide range variable speed from in-plant a-c. circuits, available from 1 to 200 hp. Instead of a motor-generator set, the Statatron uses silicon diodes and saturable reactors to rectify the current from a-c. to d-c. These work in combination with a transistorized power exciter to supply variable voltage. Statatron is compact—35% smaller than conventional units. Consists of only three components: Super 'T' d-c. motor, operator's station and control cabinet. Statatron is quiet—vibrationless and low in maintenance cost. Bulletin D-2508.



THIS MASTER GEARMOTOR drives a chip conveyor on automatic screw machine. The combination parallel and right angle reduction produces efficient low output speed at high torque—ideally suited to this operation. Features important here are its compactness and one piece construction, saving space and maintenance. This Master Gearmotor is impervious to liquids . . . splashing of coolant and any other outside contamination. Where the situation calls for gearmotors, this full line can cut your engineering and assembly costs . . . give you dependable performance. Bulletin E-2409.

TOTAL SERVICE is an integral part of every Reliance product, from engineering and start-up assistance to maintenance and renewal parts. The photo shown here is typical of a Reliance Service Engineer's on-the-job availability—for maintenance and consultation on knotty problems. Every Reliance Sales Engineering Office and Distribution Center—nationwide—gives you the attention and experience necessary to assure the top performance you expect from the Reliance equipment you buy.



RELIANCE ELECTRIC AND ENGINEERING CO.

DEPT. 11-8 CLEVELAND 17, OHIO • Canadian Division: Toronto, Ont.

SIEMAG

PROGRESS
IN ROLLING MILL CONSTRUCTION

AW 57—61

For high performance and economic service SIEMAG Rolling Mills

42" × 90" 2-Hi Rev. Blooming/Slabbing Mill.

View from Cooling Bed to Bloom and Slab Shear and Mill Stand.

Roll Body Length 90"
Max. Roll Opening 46 - 1/2"

2200 t Down-Upcut Bloom and Slab Shear:
Max. Knife Pressure 4 800 000 Lbs
Length of Knives 51"
Opening between Knives 19 - 3/4"
driven by 2 Motors of 680 HP each

All moving parts lubricated by centralized oil resp. grease lube system

SIEMAG - SIEGENER MASCHINENBAU GMBH - DAHLBRUCH (WESTF.) GERMANY

Telephone Hilchenbach, Kr. Siegen, 841
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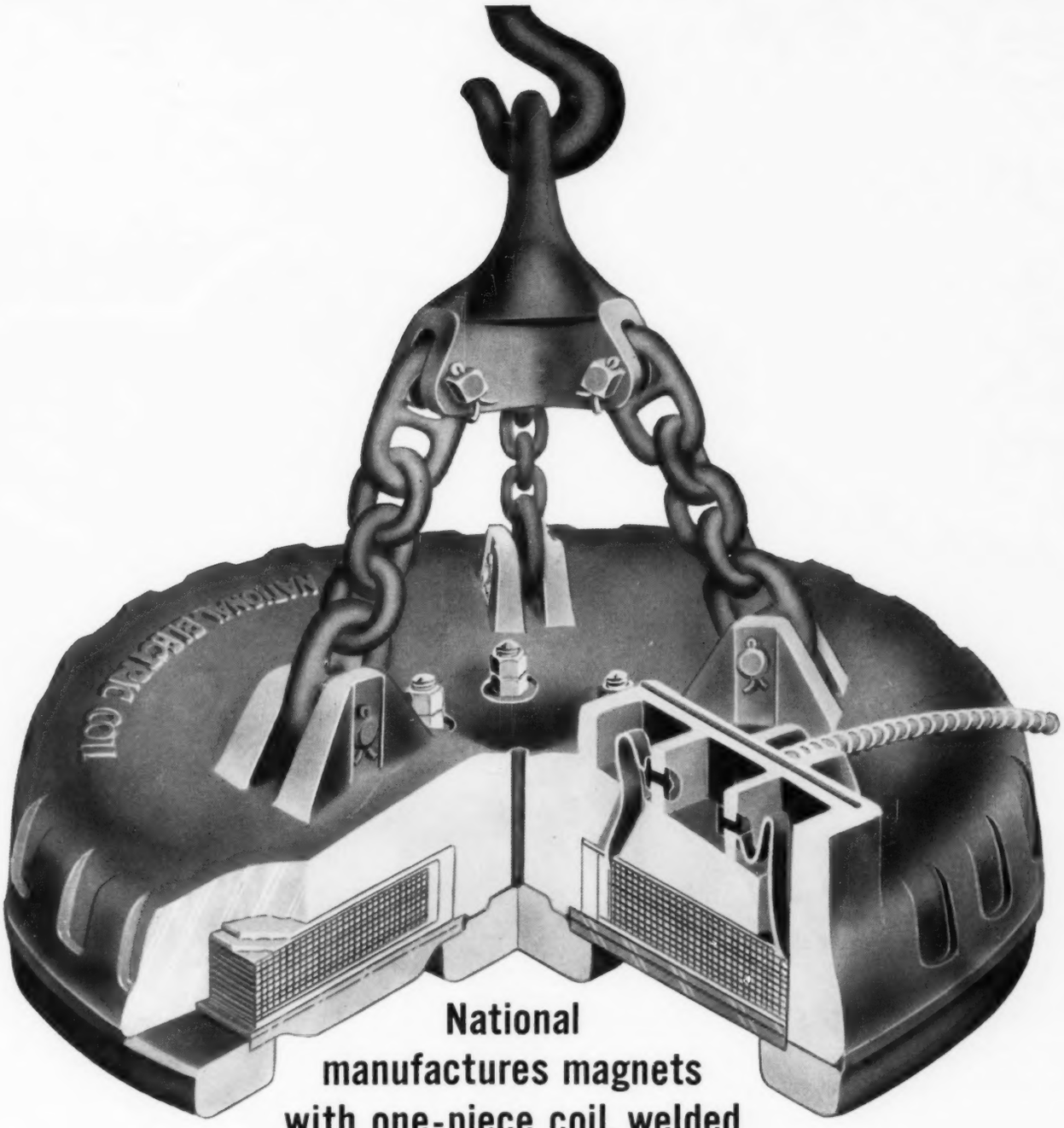

National manufactures magnets with one-piece coil, welded construction for ultimate in service

The coil in this National lifting magnet is wound on a steel spool with square wire insulated with glass fiber, and bonded into a solid mass with Epoxy resin. This feature, plus the use of all-welded construction makes National magnets tops in durability.

These magnets will withstand moisture, severe heat cycling, and mechanical shock.

National's know-how in designing and building magnets is based on years of experience in magnet overhaul and repair. Specify National for long, trouble-free service.

WRITE FOR NEW BOOKLET. Complete information on National's unique magnet design contained in this 8-page booklet. Send coupon for your copy.

National Electric Coil

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Personnel News...

Robert S. Gentz has been appointed general manager of Inland Steel Co.'s Indiana Harbor works. He was formerly assistant general manager in charge of the plant's departments which roll shape products. **Michael Tenenbaum,** formerly assistant general manager in charge of technical services, has been appointed to the newly-created position of general manager of research and quality control. In addition, **James J. Halley,** formerly superintendent of Inland's experimental iron smelting project, has been named manager of research and development. He succeeds **Edwin D. Martin,** who is retiring from active assignment but will remain in a consulting capacity until the end of the year, when he will formally retire. Mr. Gentz joined Inland in 1940 as a trainee at Indiana Harbor works. He worked in the plant's merchant mills and Sheet and Galvanizing Department, later served as director of management development and was named assistant general manager in 1956. Mr. Halley began his Inland career in 1933 as a metallurgist and was formerly chief of research and development before assuming the post of superintendent of the company's experimental smelting project.

William R. McCalister has been appointed director—industrial engineering for National Tube Div., United States Steel Corp. Mr. McCalister had been general superintendent, National Tube's Ellwood works, Ellwood City, Pa. **John D. Tyson** was appointed general superintendent, Ellwood works, succeeding Mr. McCalister. **James O. Light** was named assistant to vice president—operations succeeding Mr. Tyson. He had been division superintendent, steel works operations at the division's Lorain works, Lorain, Ohio. In additional moves, **William H. Hall** was named assistant general superintendent at Ellwood works; **Thomas W. Young** who had been director—industrial engineering, succeeded Mr. Hall as assistant general superintendent at Gary; and **John J. Hopper** was named assistant to general superintendent, Gary. He was formerly assistant general superintendent, Ellwood works.

J. R. Connell, formerly administrative assistant to the president of Jessop Steel Co., was named general manager of Green River Steel Corp., with over-all managerial responsibility for the Jessop subsidiary. **G. E. Cassidy,** formerly general superintendent, was promoted to the newly-created post of general manager—operations. His previous position will not be filled at the present time.

Joseph M. Engel has been appointed chief metallurgist for the Buffalo, N. Y., plant of Republic Steel Corp. Mr. Engel has been with Republic in Buffalo since 1939 when he joined the Metallurgical Department. He was appointed mill metallurgist in 1942 and advanced to field metallurgist in 1944. In 1947, he became supervisor of metallurgy, a position he held until he became assistant chief metallurgist in 1953.

John L. Scarry has been named assistant general superintendent—primary production at the Riverdale, Ill., plant of Acme Steel Co. At the same time, **William T. Fields,** formerly division superintendent, Cold Mill Division, was named assistant general superintendent—finishing production; and **Tad E. Jaski,** formerly assistant division superintendent, Cold Mill Division, was named superintendent of the Cold Mill Division.

Paul H. Wilson was named general superintendent of A. M. Byers Co.'s plant in Ambridge, Pa.

Leonard A. Tryner has been appointed assistant superintendent of the Mason Department at Republic Steel Corp.'s Chicago, Ill., district plant. Mr. Tryner has been with Republic at South Chicago since 1949, when he started as a mason first class. He has been a foreman in the Mason Department since 1955.

William R. Mogg, formerly assistant director of product development, has been appointed assistant director of metallury—technical services with Crucible Steel Co. of America. Mr. Mogg joined Crucible in 1958

R. S. GENTZ

W. R. McCALISTER

J. D. TYSON

J. O. LIGHT

H. F. KAISER

H. H. CHAPIN

R. J. GARMY

K. E. BUFFINGTON

as sales manager at the company's Spring Div. The following year he was appointed general manager of the division, and in 1960 he was transferred to the company's general offices as assistant director of product development.

Herman F. Kaiser has been named assistant manager of Republic Steel Corp.'s central alloy district. Mr. Kaiser, who has been with Republic in Canton and Massillon since 1928, has been divisional superintendent of the company's Massillon operations since October, last year.

Howard H. Chapin was named general superintendent of Republic Steel Corp.'s Southern District. He was formerly superintendent of the company's cold strip mill in Cleveland, Ohio. The position of Southern District general superintendent has been vacant since Jan. 1, 1959, when **T. H. Hagan** was promoted from that job to assistant district manager. Mr. Chapin has been with Republic since 1934, when he became a roller on a reversible mill at Warren, Ohio. In 1937 he transferred to Cleveland as finishing mill foreman. In 1951 he became assistant superintendent of the Cleveland 98-in. cold strip mill, and superintendent in 1954.

R. J. Garmy has been appointed superintendent of the new 56-in. hot strip mill at Republic Steel Corp.'s Warren, Ohio, plant. Mr. Garmy joined Republic in 1946 as a member of the Electrical Department at the company's Canton, Ohio, plant. He was made an electrical engineer in 1947 and in 1955 was promoted to assistant chief engineer at Canton. For the past two years, he has been assistant project engineer at the Warren plant.

Kenneth E. Buffington has been promoted to supervisor of maintenance planning and scheduling in the Maintenance Planning Department of Lukens Steel Co. He was formerly chief maintenance co-ordinator. He has been with Lukens since 1947.

James Antizzo has been elected vice president of Tata Inc.

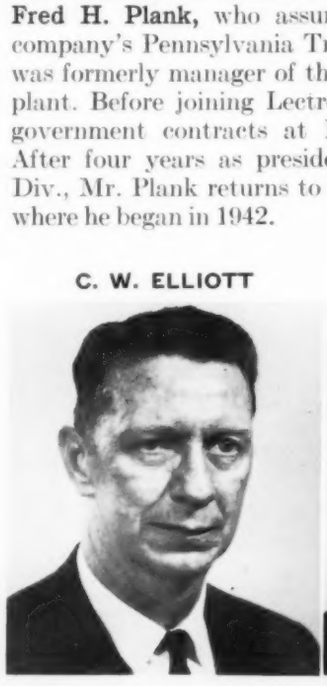
Donald E. Moat, formerly vice president and director of marketing, Leeds & Northrup Co., was named vice president—government and foreign relations, and **John F. Quereau,** formerly vice president and director of manufacturing, was named vice president and director of marketing. **Elwood F. Rogge,** former manager of the North Wales plant, becomes director of manufacturing. **J. Frederick Schock,** who was manager of the Order Control Division, becomes, in addition, local manager at North Wales. **William M. Feeley,** formerly head of the plant engineering and maintenance section, becomes manager of the Plant Engineering and Services Division.

Thomas L. Dinnen has been named manager of the Cleveland, Ohio, district, Allis-Chalmers Manufacturing Co.'s industries group. He had been manager of general industrial sales in the Cleveland district since 1959 and prior to that manager of metals industry sales. He succeeds **Joseph Bronaugh,** who becomes manager, utility sales, Baltimore, Md., district.

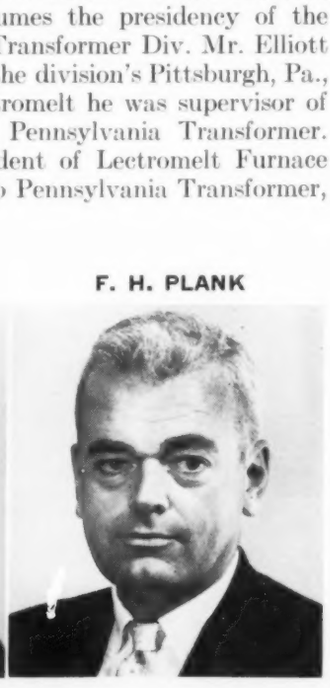
E. R. Bellows has been appointed manager of eastern castings sales, foundry and mill machinery group, Blaw-Knox Co., succeeding **B. P. Hammond,** who has retired. Mr Bellows joined the company in 1940 and served in foundry production capacities until 1954, when he entered sales work. He served as Washington sales and engineering representative for two years and during the past year has been assistant to Mr. Hammond.

Claude W. Elliott has been named president of Lectromelt Furnace Div., McGraw-Edison Co. He succeeds **Fred H. Plank,** who assumes the presidency of the company's Pennsylvania Transformer Div. Mr. Elliott was formerly manager of the division's Pittsburgh, Pa., plant. Before joining Lectromelt he was supervisor of government contracts at Pennsylvania Transformer. After four years as president of Lectromelt Furnace Div., Mr. Plank returns to Pennsylvania Transformer, where he began in 1942.

C. W. ELLIOTT



F. H. PLANK



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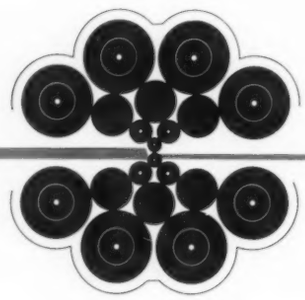
Report:

THIN GAUGE TINPLATE



How Sendzimir Mills help you compete in this growing market at an extra profit per ton

The growing market for thin tinplate below .008″ thickness presents tinplate producers with both a problem and an opportunity.

The problem is not only to gain extra capacity for rolling these new gauges, but to achieve three other benefits:

a — reduce the normal production losses of lowering the finish gauges on present tandem equipment

b — eliminate the additional downtime of extra roll maintenance

c — provide the flexibility to take short runs

THE ECONOMICS

From a profit standpoint, thin gauge tonnage can be best achieved by combining present tandem facilities with a Sendzimir Mill. The tandem mill will roll approximately double the thickness required and supply coils to the Sendzimir Mill for single pass rolling to finished gauge. This provides an immediate tonnage gain from the tandem mill, since the finishing is on the separate Sendzimir Mill and eliminates the tonnage loss from lowering finish gauge on the tandem mill. Thus rolling time will be made available for the finishing of heavy gauge tinplate by the tandem mill.

SHORT-RUNS

Beyond the profit possibilities in producing thin gauge tinplate, the tandem and Sendzimir combination offer other production benefits.

You get the flexibility to make short runs with minimum interference to production on either coated tinplate, annealed or full hard black-plate. Actually, the Sendzimir Mill can make short runs of any low carbon steel rolled on the tandem mill and do it at a profit.

HOT MILL BENEFITS

Finishing lighter gauges on the tandem mill normally require lighter starting gauges. But with the Sendzimir Mill available, the hot rolled coils to be run at semifinished gauges can be substantially heavier, thus increasing production off the hot mill.

INSTALLATION AND OPERATING COSTS

The compact Z-Mill permits low foundation and installation costs. Less building area is needed. The small work rolls of the Z-Mill are replaced in seconds, reground faster on smaller grinders, handled easily. Downtime is reduced, operating efficiency is higher.

FINISHED PRODUCT

The Sendzimir Mill adds to your capacity a product quality unmatched by any other rolling system.

Strip flatness is maintained by adjustment of mill shape through the power crown control while the mill is operating. Strip edge pressure is controlled by lateral adjustment of the tapered intermediate rolls.

It is never necessary to compromise on surface quality because freshly ground work rolls are inserted so readily that consistently superior strip finish can be attained.

Because the smaller work rolls respond more readily to gauge adjustments, gauge is held more accurately and heavy ends can be brought into tolerance for an increase in yield.

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W. H. McCORMICK

R. T. EAKIN

J. J. OFFUTT

ARTHUR LIND

William H. McCormick has been appointed company metallurgical engineer for the Crucible Steel Co. of America. Formerly assistant director of metallurgy—customer technical services, he has been associated with Crucible since 1923 when he started as timekeeper at the company's Crescent works in Pittsburgh. Later that year the plant merged with Park works and Mr. McCormick was transferred to the Open Hearth Department. He held positions as sheet mill foreman, metallurgist, assistant chief metallurgist, manager of alloy steel sales and chief works metallurgist. He was transferred to the company's general offices in 1955 as product sales manager—alloy and carbon. In 1960 he was named assistant director of metallurgy—customer technical services.

Robert T. Eakin has been appointed vice president in the Engineering and Construction Div. of Koppers Co., Inc. He will be in charge of all Koppers activities in connection with the long-term management contract, signed recently by Koppers de Venezuela, C.A. and Corporacion Venezolana de Guayana, a steel firm headquartered at Caracas, Venezuela. Prior to joining Koppers earlier this year, Mr. Eakin was vice president of operations and a member of the board of directors of Latrobe Steel Co. He started with Allegheny Ludlum Steel Corp. as a staff metallurgist in 1940, and advanced to chief metallurgist of the Brigham Road Division at Dunkirk, N. Y. In 1950, he was named assistant to the vice president and technical director of Allegheny Ludlum's Brackenridge, Pa., works. A short time later he was promoted to works manager. He remained at Brackenridge until 1958 when he joined Latrobe Steel.

J. James Offutt was elected executive vice president of the A. P. Green Fire Brick Co. Mr. Offutt was formerly vice president and general manager responsible for the functions of sales, research and operations. He became a vice president in January, 1958, and was appointed director of sales. He was elected a director of the company in April of this year.

Arthur Lind has been appointed to the position of project engineer of the Rolling Mill Division of the E. W. Bliss Co. With the Bliss organization since 1949, Mr. Lind was previously an erection engineer and chief draftsman.

Jack Wade was named by Dravo Corp. as superintendent for the construction of the Stora-Kaldo oxygen steelmaking facility at the Roemer works of Sharon Steel Corp. **W. H. Ryan** and **W. S. Schwarzl** were named project engineers for the construction and mechanical phases of the installation.

Fred Kamena was named chief design engineer, Hydraulic Press Division, The Youngstown Foundry & Machine Co. Also named were **Stanley T. Bowden** and **Joseph Mein** to direct the division's sales throughout the world. Mr. Bowden will be located in the home office at Youngstown, Ohio. Mr. Mein will be located in Montreal, Canada.

Joseph E. Zwit has been appointed vice president for sales, Engineering Div., Hauck Manufacturing Co. He was formerly sales manager of the division. Mr. Zwit succeeds **William H. Oler,** who has resigned. Mr. Oler will remain active in the company as a member of the board of directors. Mr. Zwit has been with Hauck since 1956 when he joined the Chicago district sales office. He served as central regional manager in Chicago before being transferred to Hauck's main office as Equipment Division sales manager.

Charles D. Schmidt, previously on the sales staff of the Chicago office, has been named manager of the Detroit district sales office, Whiting Corp.

George A. Brunner was appointed assistant district sales manager, Pittsburgh district, of the Refractories Division, E. J. Lavino & Co. At the same time, **Harry J. Hausner** was named assistant district sales manager, Chicago district, and **John N. Herbst,** assistant district sales manager, Philadelphia district.

Z. W. Whitehouse, superintendent, Electrical Department, Republic Steel Corp., Canton, Ohio, and **J. D. Kelvie,** electrical superintendent, Republic Steel Corp., Massillon, Ohio, have retired.

Bruce A. Fountain has been named electrode products sales representative in Chicago for National Carbon Co., Div. of Union Carbide Corp. He succeeds **Charles A. Taussig,** who has been assigned to the Electrode Product Technical Service Department in New York, N. Y. Mr. Fountain joined National Carbon in 1942 in the Production Department at Niagara Falls, N. Y. In 1954 he was transferred to the Electrode Products Technical Service Department. He was electrode prod-

(*Please turn to page 178*)

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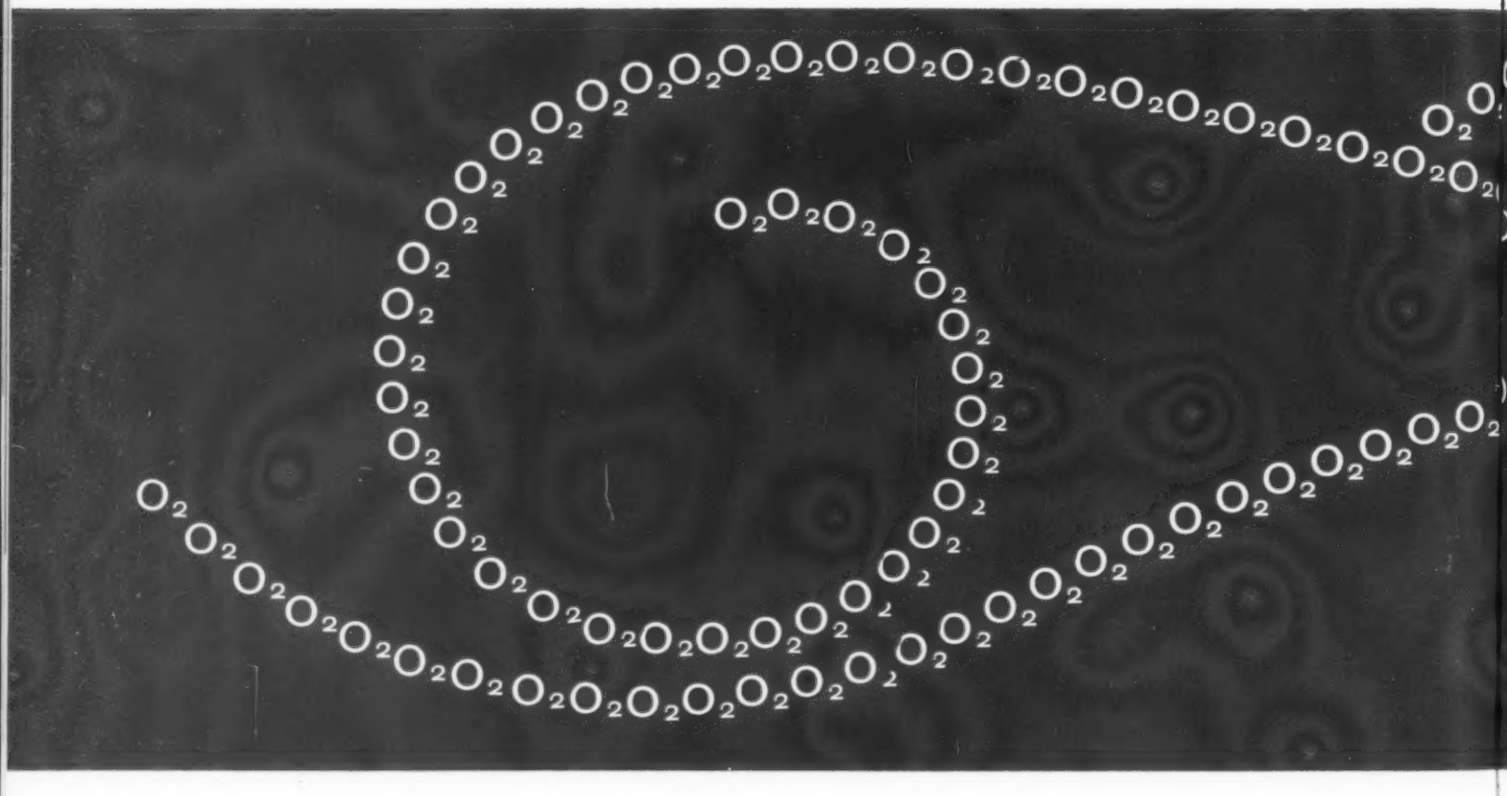
OXYGEN FOR STEEL IS ALWAYS ON TAP WHEN YO



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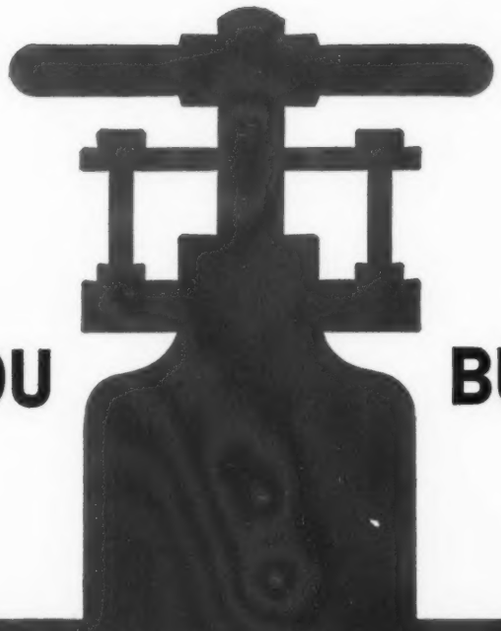

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S. E. SPECHT (left)
G. R. EUSNER (center)
F. M. MILLER (right)

(*Continued from page 175*)

ucts salesman in the Niagara Falls territory from 1956 until 1959, when he was transferred to New York.

Schaeffer E. Specht was appointed general sales manager for the Buell Engineering Co. In his new capacity, Mr. Specht will supervise all sales operations for Buell Engineering and its Northern Blower Division in Cleveland, Ohio. He was formerly western district sales manager.

George R. Eusner, formerly division chief, Refractory & Mineral Technology Division, United States Steel Corp., at Monroeville, Pa., has been elected executive vice president of The Davis Fire Brick Co.

Francis M. Miller has been appointed superintendent of the Electric Department at Dravo Corp.'s Neville Island, Pa., plant. Mr. Miller joined Dravo in 1957 as electrical superintendent on iron ore sinter plant construction projects. He was formerly with Bethlehem Steel Co. in Bethlehem, Pa.

William G. Benz was named director of quality control, Combustion Engineering, Inc. Mr. Benz joined the company's Quality Control Department in 1960. He previously served with U. S. Steel Corp., Air Reduction Sales and M. W. Kellogg.

Charles J. Hendrickson has been appointed manager of national accounts for the Insulation Div. of the M. H. Detrick Co. He will be headquartered at the company's New York office.

Charles R. Hauth was appointed assistant manager, technical sales, Harbison-Walker Refractories Co. Mr. Hauth joined Harbison-Walker's Research Department in 1948 and has since served in general sales in Pittsburgh Pa., as sales engineer in the Chicago, Ill., district sales office and more recently with technical sales in Pittsburgh.

Charles R. Wilt, Jr., has been appointed assistant chief engineer, Selas Corp. of America. Mr. Wilt joined Selas in May, 1960, as assistant to the chief engineer, coming from Loftus Argentina Industrial Y Tecnica, S. A., San Nichols, Argentina, where he served as resident engineer. Previously he was process furnace engineer for Reynolds Metals Co., and, prior to that, served as assistant chief engineer for Loftus Engineering Corp.

Joseph P. Benz has been appointed vice president in charge of national sales for Palmer-Bee Co. **David F. McFadden** has been appointed assistant chief engineer. Previously he was associated with Jones & Laughlin Steel Corp.'s Engineering Department.

H. James Smith was appointed assistant superintendent of production at The Youngstown Sheet and Tube Co.'s Indiana Harbor works. Mr. Smith joined the company in 1952 as an industrial engineer. He was promoted to sheet mill shipping foreman in 1954 and a year later became shipper in the Hot Strip Department.

W. P. White, Jr., has been appointed executive vice president of Appleton Electric Co. Mr. White was formerly associated with the Continental Can Co. and the White Cap Co.

John V. Haider was named manager of the Pittsburgh sales district, Pangborn Corp. Previously sales engineer, he succeeds **John D. Wise,** who retired recently after 14 years as Pittsburgh district manager. At the same time, **Melvin R. Price** joined Pangborn as sales engineer, Pittsburgh District.

L. J. Frick has been named to the new position of manager, Industrial Equipment Division sales, Midwest region, Industries Group, Allis-Chalmers Manufacturing Co. Since 1959, Mr. Frick had been manager, general industrial sales, St. Louis district. He is succeeded in that post by **J. C. Treible.** Mr. Frick has been with Allis-Chalmers since 1942 and has been a sales representative in the St. Louis district for the last 15 years. Mr. Treible has been a sales representative in the St. Louis district since 1958. Prior to that he was an application engineer in the Industrial Systems Department for several years.

Dr. D. M. Gillies was appointed director of research for Union Carbide Metals Co. He succeeds **Dr. F. J. Shortsleeve** who has been appointed a product manager for the company. Prior to his new appointment, Dr. Gillies was assistant director of research for the laboratories of Linde Co., Speedway, Ind. He joined this division of Union Carbide in 1944 as chief chemist for Linde Co. on the Manhattan Project. Before that time, he had done research on the Manhattan Project at Columbia University.

Charles E. Altmeyer was elected to the post of executive vice president of Chandeysson Electric Co.

Keith Mottet has joined the Cincinnati, Ohio, office of The Falk Corp. He will work under the direction of **Kenneth W. Morrissey** in the Cincinnati territory which includes nine counties in Ohio.

Joseph C. Carey has been appointed sales manager, Chain Division of The McKay Co. Mr. Carey succeeds **Rowland Erving** who has become director of the company's newly-created Market Research Department. Mr. Carey has been assistant sales manager of the Chain Division and prior to that was district representative covering Western Pennsylvania and most of West Virginia from headquarters in Pittsburgh.

Dr. Thomas H. Manninen has been appointed technical assistant to the president of Air Reduction Chemical & Carbide Co., a division of Air Reduction Co., Inc. With Airco since 1954, Dr. Manninen was formerly director of chemical research and engineering at the central research laboratories of Air Reduction Co., Inc. From 1936 to 1954, he was associated with the U. S. Industrial Chemicals division of National Distillers at the Stamford, Conn., and Baltimore, Md., research laboratories.

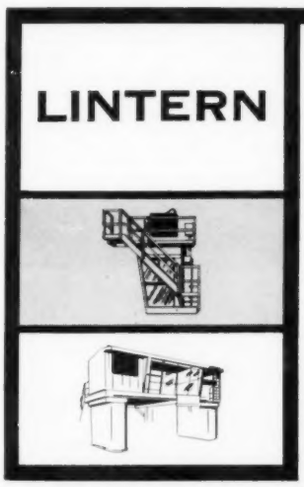
Leonard J. Linde has been appointed director of engineering, Industries Group, Allis-Chalmers Manufacturing Co. Previously, he had been director of engineering services since August, 1960. Mr. Linde joined Allis-Chalmers in 1950 and for the next four years served as assistant general manager and chief engineer of the Boston works. He was transferred to West Allis in 1954 and appointed director of electrical engineering for the company.

Peter L. Della Donna has been named manager of the Cleveland sales office of Heppenstall Co. and Midvale-Heppenstall Co. He succeeds **Robert E. O'Brien.** Mr. Della Donna started at the Bridgeport, Conn., plant of Heppenstall in 1930 as a machine operator, and was promoted to production manager in 1940. He was named a sales representative in 1946.

John S. Kratz has been appointed product sales manager—metallurgical products, Chemical & Metallurgical Division of Sylvania Electric Products Inc.

Obituary

John P. Kelly, General Sales Manager, Gould National Batteries, Inc., died July 31.



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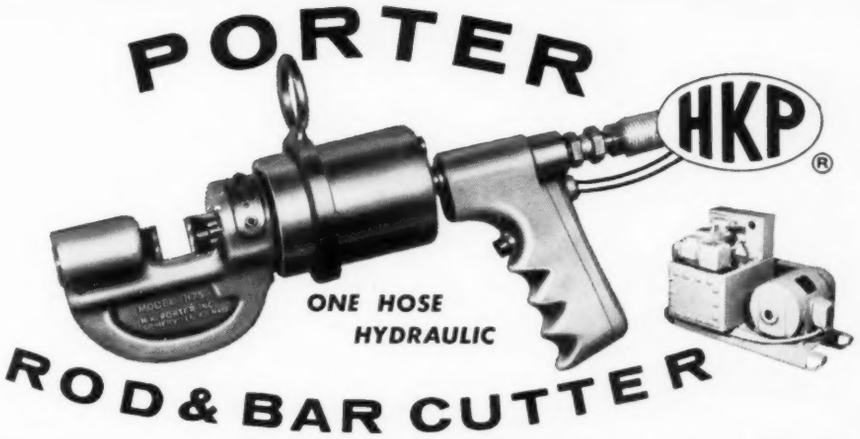

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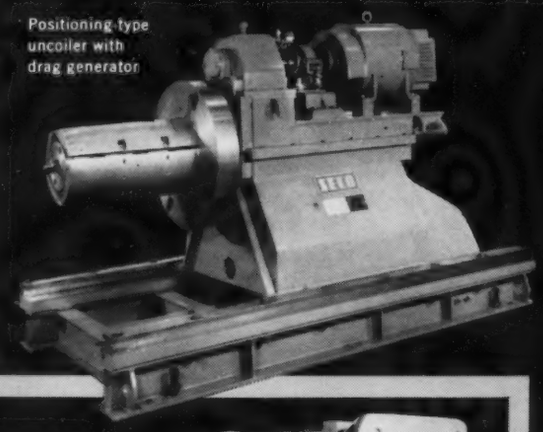
Positioning-type uncoiler with drag generator

Predictable Performance

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SECO

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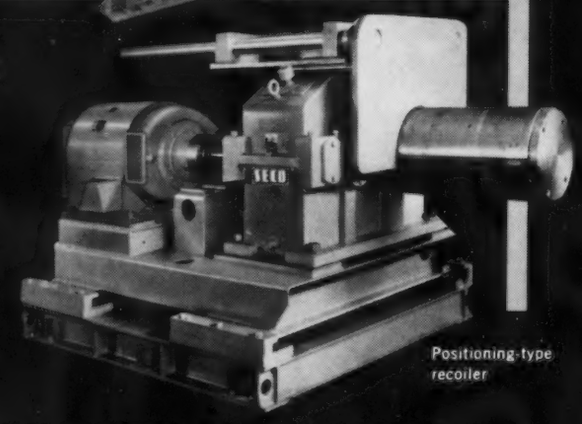
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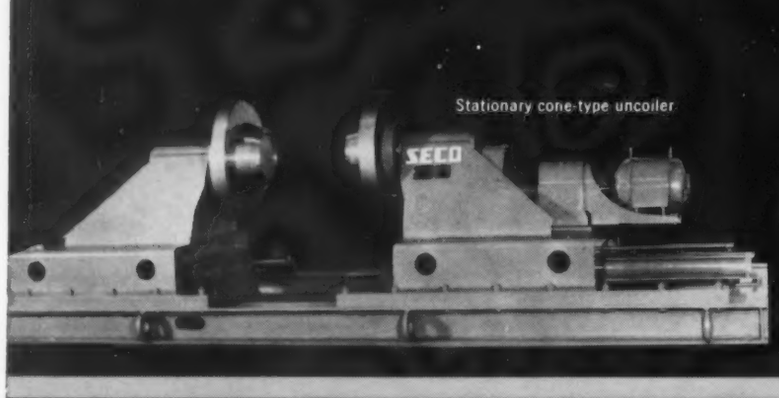
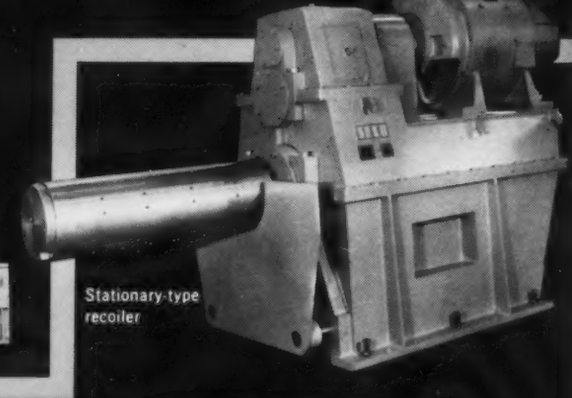
SECO also makes auxiliary equipment such as coil cars with coil lifts to simplify uncoiler loading and recoiler unloading. Available for mandrel or cone-type reels.

A staff of trained sales engineers will assist you in finding the equipment best suited to your needs. Call or write today. West Coast representative: United Machine Tool Company, Los Angeles.


Stationary cone-type uncoiler


Stationary-type recoiler

SECO STEEL MILL EQUIPMENT

- Leveling and Shearing Lines
- Combination Edging and Flattening Lines
- Tension Reels for Strip Polishers
- Narrow Strip Grinding Machines
- Slitting Lines
- Multiple Strand Pull-out Rolls and Take-up Frames
- Strip Coilers (Up and Down Type)
- Traverse Reels for Narrow Strip
- Steel Coil Up-enders
- Scrap Ballers

Affiliated with Lee Wilson Engineering Co., Inc.

STEEL EQUIPMENT COMPANY

P. O. BOX 737, WARRENSVILLE STATION • CLEVELAND 22, OHIO

Equipment News...

STRAIGHTENER-CUTTER

△ The Lewis Machine Co. has added another new model for shapes to their line of wire straightening and cutting machines.

The No. 21-FHA travel-cut shape straightening and cutting machine, has a capacity of $\frac{5}{16}$ in. to $\frac{13}{16}$-in. sq or hex mild steel or equivalent area in shapes and flats up to 2-in. wide.

The outstanding features of this newly designed model are the improved low-inertia flying-shear cutoff and a simplified electric trip mechanism independent of the gaging mechanism making possible much higher production.

The machine is designed to take the stock from the coil, straighten and cut automatically to accurate predetermined length.

The straightener consists of a three-roll preliminary straightener which breaks the coil bow, an eight-roll horizontal straightener for edge straightening, and an eight-roll vertical straightener for finish straightening. All roll shafts are power-driven and mounted on roller bearings. The entire horizontal straightener housing is adjustable in the horizontal plane to compensate for various stock width. The upper rolls in the vertical housings and the front rolls in the horizontal housing are individually adjustable for proper roll pressure and offset.

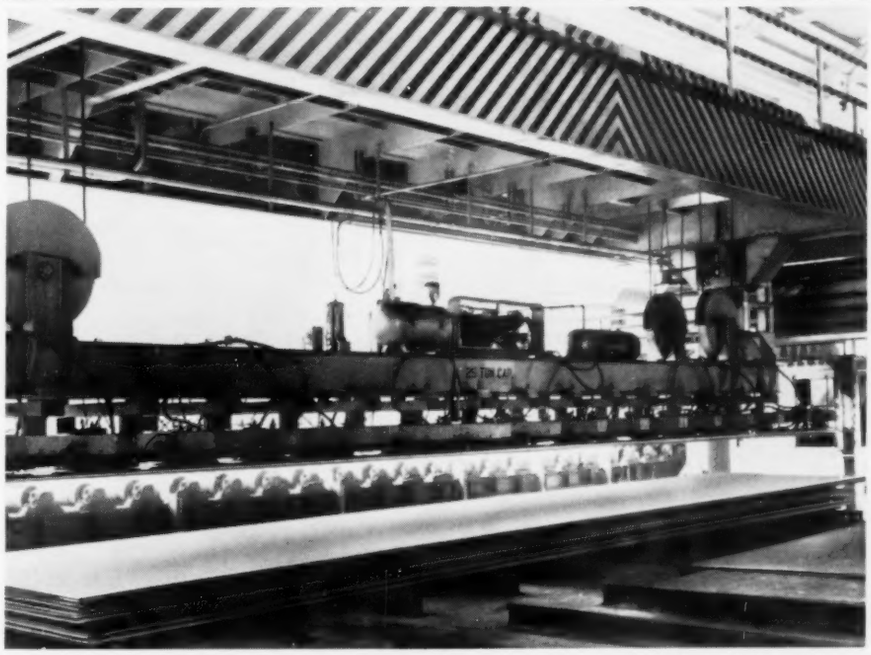
A two-speed sliding gear feed transmission has positive feed speeds of 150 and 195 fpm.

The cutoff is the newly designed high-speed travel-cut flying-shear type which travels with the rod and cuts while in motion. A single crank-driven lever provides both the longitudinal travel and the vertical cutting stroke and eliminates all cams, springs and loose links; thereby assuring positive and accurate cutoff action without the high inertia and shock of conventional mechanisms. A variable speed moto-drive independently drives the flywheel and cutoff and permits accurate synchronization of the cutoff head speed with the feed speed, thus making possible the elimination of feed roll marks on the rod. An air clutch and brake assures fast, positive and smooth engagement and reduces maintenance to a minimum.

A low-inertia electric trip mechanism is especially designed to assure positive tripping of the clutch at high speed. The wire or rod traveling through the split guide bar engages the limit switch finger and by direct electrical connection energizes the clutch and brake solenoid valves. The only inertia involved is that of the limit switch finger.

The length gage has only one job—gaging to length. Tripping has been divorced from this function—thus eliminating loose slides, springs and latches. The wire or rod engages the end of the gage rod which is fastened solidly through the release links to the flying shear. This system provides a positively driven gage without the inertia of floating parts. Changing the cutting length is accomplished by merely setting the limit switch finger and the gage rod to the desired length.

VACUUM GRAPPLE TRANSPORTS HEAVY PLATE



A vacuum grapple handling all shapes, sizes and gages of steel plate interchangeably provides the means for fast, safe, efficient transport of finished pieces ranging from 3-ft sq to 48 ft x 13 ft-6 in. at United States Steel Corp.'s Homestead works. Steel flowing down the production line is stopped and a semi-gantry crane equipped with the grapple is lowered onto the steel. Automatic vacuum cups firmly attach and the crane conveys the plate to the appropriate stockpile. As there are no mechanical grabs, the mechanism is not restricted by the size or shape of plate. Plate up to 2-in. thick is handled with a 4.1 safety factor. The vacuum grapple, one of three in use at Homestead, is manufactured by the Noble Co.

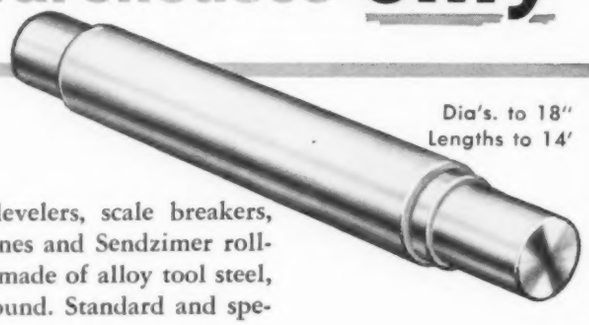
INGOT BUGGY CONTROL

△ Prodac control from the Westinghouse Electric Corp. supplies static sequence control of ingot delivery using tables and dual transfer cars at the U. S. Steel Corp.'s Fairless works.

The ingot buggy is cable drawn and derives its basic position-sensing information from Rotrac

For STEEL MILLS

and warehouses *only*



Dia's. to 18"
Lengths to 14'

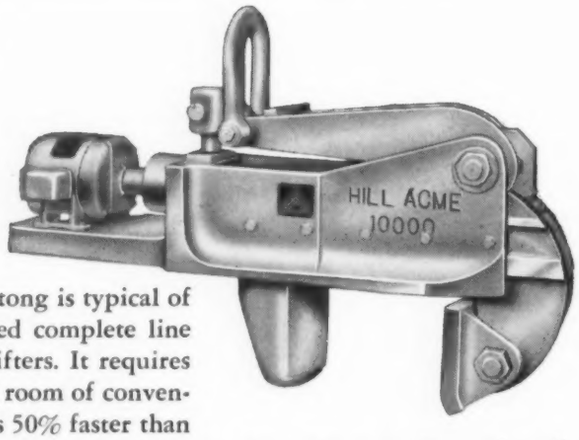
"HILL ACME" ROLLS

Custom made for levelers, scale breakers, straightening machines and Sendzimer rolling mills. Precision made of alloy tool steel, heat treated and ground. Standard and special types.

"CLEVELAND" METAL CUTTING KNIVES

The product of forty years of experience in manufacturing alloy grade, metal cutting knives of all types for shearing hot and cold metals.

"HILL ACME" MOTORIZED LIFTERS



This vertical coil tong is typical of the newly designed complete line of HILL ACME lifters. It requires only 1/3 the head room of conventional tongs and is 50% faster than mechanical types. Gives a constant grip ratio regardless of wall thickness and can be prepositioned to eliminate damage to the coil. Available up to 80,000 lbs. capacity. Contact us for "C" hooks, Rack Lifters, Billet, Sheet, Plate, Bar, Ingot and Ingot Mould Lifters.

THE HILL ACME COMPANY

1201 West 65th Street • Cleveland 2, Ohio

MANUFACTURERS OF: "HILL" Grinding and Polishing Machines • "ACME" Forging Machines • "CANTON" Rotary and Alligator Shears • BAR-BILLET Shears MATERIAL HANDLING Equipment • "CLEVELAND" Knives and Shear Blades.

contactless pulse generator. Pulse information is supplied relative to angular motion of the cable drum and independent of velocity.

Position reference information comes from a circular patchboard which can be adjusted in one-foot increments for the total travel of the ingot car.

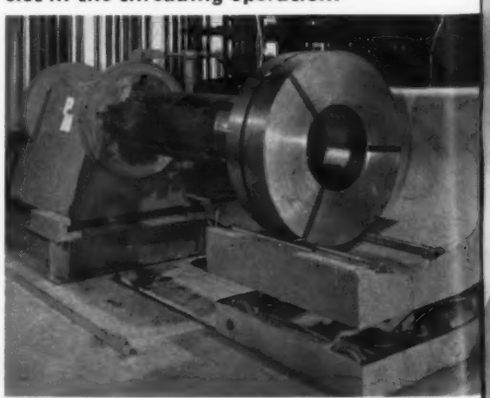
One feature of this system is that selection of position for the ingot buggy is made from one of three pit cranes on a sequence and priority basis. From the pit crane, the operator may call the buggy and send the buggy to the discharge position and maintain his call priority, or he can release his call priority and initiate emergency stop.

The ingot buggy delivers an ingot to the receiving table and, by means of hot metal detectors, the ingot is sensed and sent on its way to the mill via roll tables and transfer cars under the control of the static logic sequence system.

Located above the pit position patchboard is a complete internal test facility for checking the operation of the equipment on a simulated basis.

FLOOR-TYPE BUGGY

This floor-type hydraulically-operated coil loading buggy, offered by Production Machinery Corp., travels on rails set in the floor and features a self-contained hydraulic lift and reverse. It offers a fast and efficient means of accurately positioning coils on the uncoiler mandrel; and, it allows for storage of another coil, permitting it to be loaded whenever a crane or lift truck is available—thus preventing costly downtime in line operation. This unit is furnished complete, requiring only a source of electrical power. Installation is inexpensive. Optional features include heavy duty blocker rolls set into the cradle to assist in the threading operation.



MURRAY MAKES PROGRESS

in Electrical Construction, in Steel Mills, Automobile Manufacturing Plants, and in Heavy Industry . . . .

• Capital investment equipment starts producing sooner when the Murray organization is executing your construction projects. In a diverse field of industrial activity, Murray-Men are making a reputation for completion of contracts substantially ahead of schedule. This is an important factor in planning for increased productivity. You will find it to be good business to include Murray in your plan for future expansion.

DAVID W. MURRAY COMPANY

Detroit • Toledo • Cleveland • Pittsburgh

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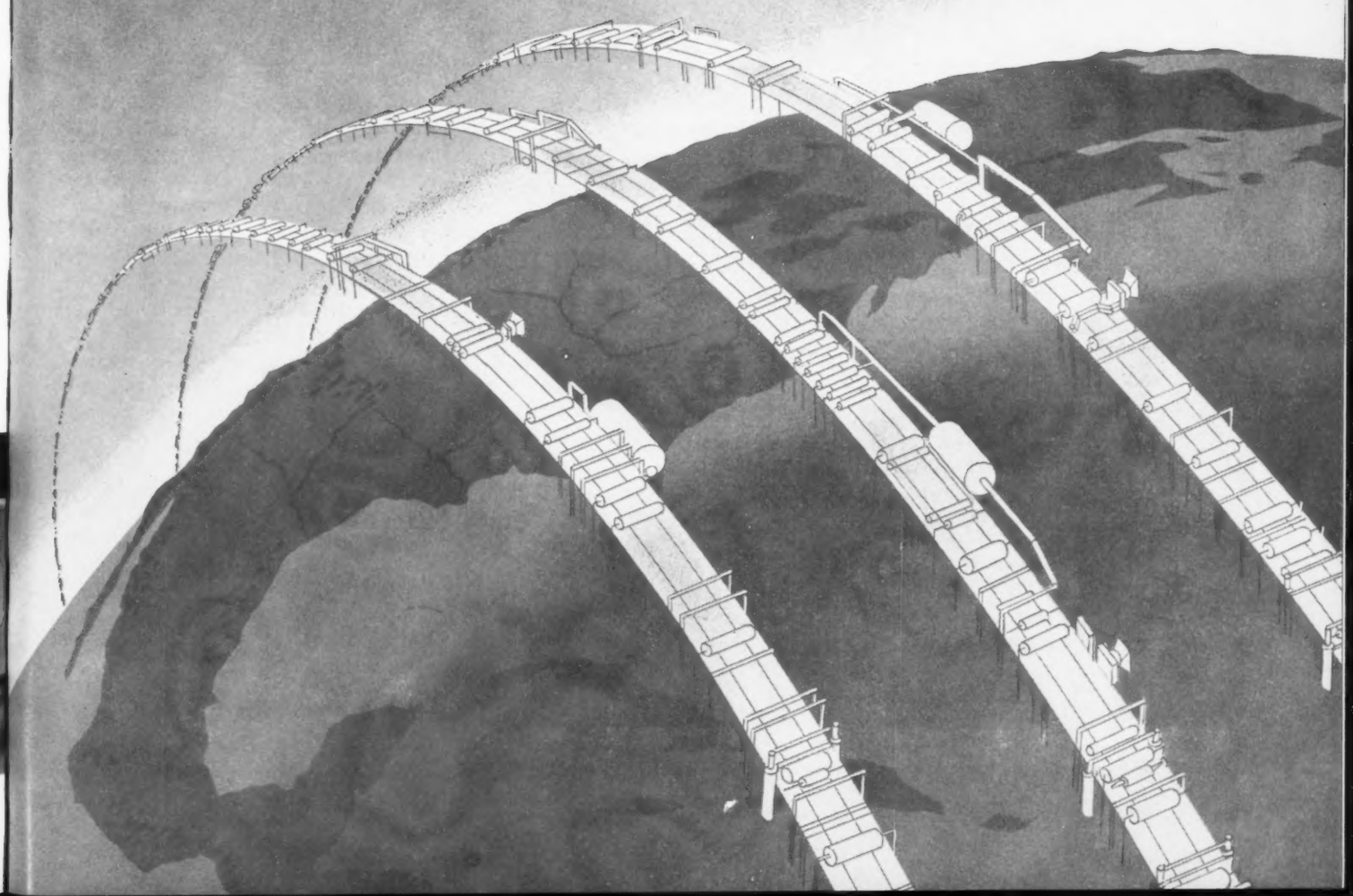


"PASSING THE BATON"— FROM WHITING TO WHITING

The big Whiting Distributing Ladle has been storing the melt. Slag, rising to the top, has hardened to form a natural lid and retain the heat below. Now the "baton"—a stream of slag-free metal—is passed through the outside teapot spout into a Whiting Pouring Ladle with bottom tap for final relay to the molds.

This scene is typical of efficient foundry operations throughout the world. Whiting engineers, practical foundrymen themselves, have designed more than 200 types and models of metallurgical ladles to reduce costs, speed output and improve casting quality in every pouring operation. If you have a special need, they'll design a special ladle to meet it precisely. And there is no charge for this service. See your local Whiting rep or write direct.

FREE: Bulletin FY-163-R, *WHITING LADLES.* Forty pages of illustrated ladle models and accessories to cut your casting costs. Write for it today. *Whiting Corporation, 15655 Lathrop Avenue, Harvey, Illinois. In Canada: Whiting Corporation (Canada) Ltd., 350 Alexander Street, Welland, Ontario, Canada.*

90 OF AMERICA'S "FIRST HUNDRED" CORPORATIONS ARE WHITING CUSTOMERS

WHITING

MANUFACTURERS OF CRANES; TRAMBEAM® HANDLING SYSTEMS; PRESSUREGRIP; TRACKMOBILES®; FOUNDRY, RAILROAD, AND SWENSON CHEMICAL EQUIPMENT

FOUNDRY EQUIPMENT

FORK TRUCKS

△ A new line of heavy-duty 10,000 and 12,000-lb capacity electric-powered fork trucks—designated the "Spartan" F-52T Series—has been introduced by The Elwell-Parker Electric Co.

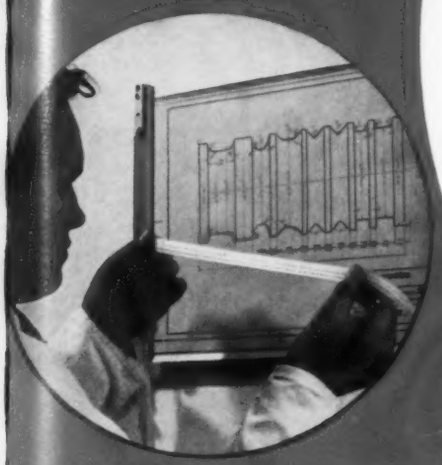
The sit-down type electric trucks are engineered to provide greater maneuverability and stamina while handling heavy loads. The drive axle, trail axle, frame and other major components of both models are designed to handle 12,000-lb loads; only minor modifications are made when the truck rating is reduced to 10,000-lb capacity. This provides capacity to spare.

When fully loaded, each of the models is capable of travel speeds of 5 to 6 mph, and lift speeds up to 32 fpm. Designed for 36, 48 or 60-volt power supply, the large compartment will accommodate a 1280 AH battery, sufficient for a full eight-hour operating shift. Convenient automotive-type controls produce controlled acceleration through four forward speeds and four reverse speeds with no plugging.

The worm-and-gear primary and dual spur gear secondary drive reductions share the load, to reduce gear loading and maintenance requirements. The high copper content electric drive motor, engineered and built by Elwell-Parker especially for heavy-duty truck service, is center-mounted on the drive axle to balance the axle load and permit the use of equal-length drive shafts. Safe control is provided by hydraulic wheel brakes.

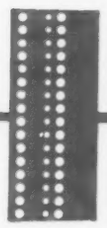
The rugged frame of the F-52T models employs center-sill construction which permits mounting all major assemblies—drive axle, steering axle and uprights—directly on the load-bearing frame members. They can be easily removed for bench repairs without disturbing adjacent parts. Cross-bracing and heavy skirts rigidly reinforce the frame and protect the undercarriage from physical damage.

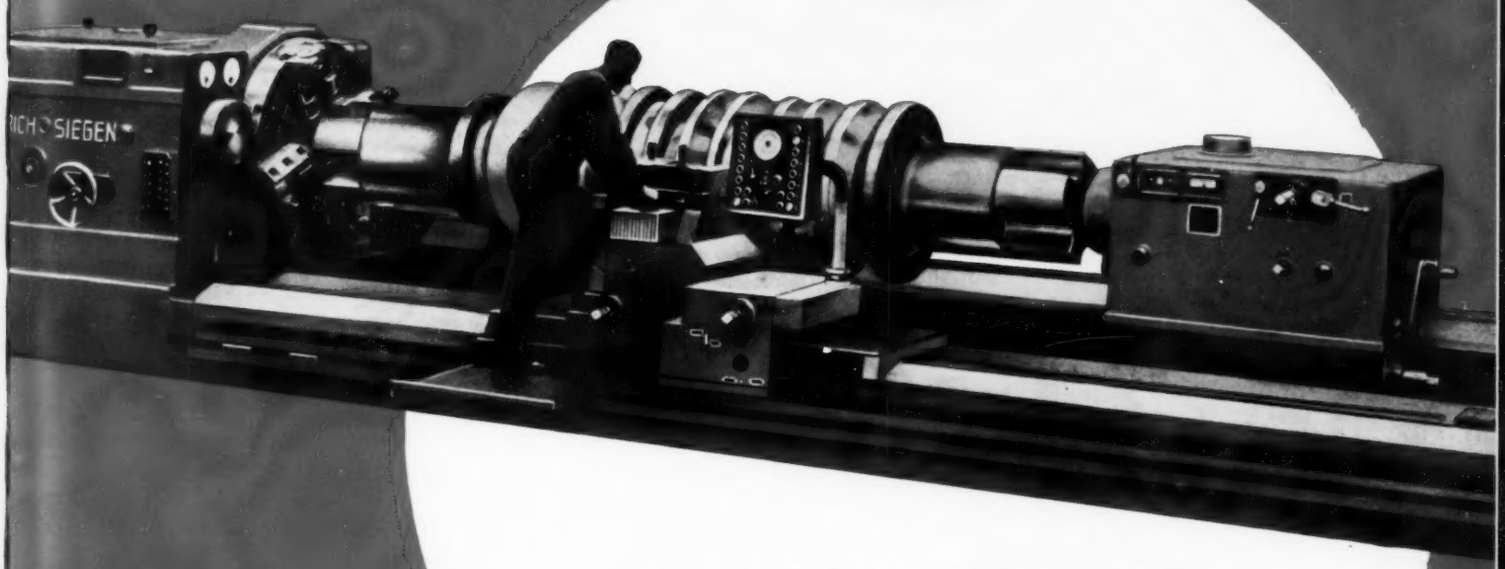
The new trucks pivot tightly around their drive wheels, for improved handling and placement of loads in narrow aisles and docks, and for precise car-loading. A flat, caster-type steering axle provides a shorter turning radius with perfect steering geometry. Wheels cannot scrub, and stress on steering linkage is eliminated. The power steering cyl-



NEW DEVELOPMENT
by WALDRICH SIEGEN

Outstanding West German Heavy Machine Tool Manufacturer





NUMERICALLY CONTROLLED ROLL GROOVING LATHE

No need for specially trained operators
No templates
Longer service life of rolls, as our positioning system computes automatically the most favorable position of grooves.

WALDRICH SIEGEN

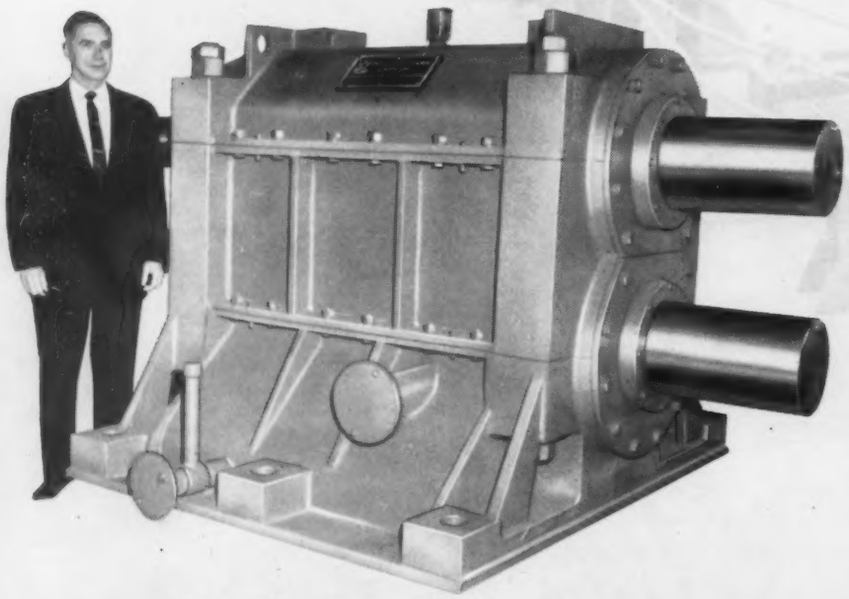
H. A. WALDRICH G. M. B. H. SIEGEN · GERMANY

AMERICAN WALDRICH MFG. CORP. • 1232 Penn Avenue, Pittsburgh 22, Pa.

HOW WESTERN GEAR SERVES THE STEEL INDUSTRY

A BLOOMING MILL PINION STAND WITH ANTI-FRICTION BEARINGS!

Designed and built on the West Coast, this 2-high pinion stand was completed in 10 weeks time from drawing board to customer's plant. Equally as important as speed of delivery are the distinguishing marks of Western Gear quality built into this blooming mill drive—as in all key steel industry products. Anti-friction bearings on alloy steel shafts—protected double shaft seals—through-hardened precision cut gears for smooth, silent efficiency—and integral lubrication—are exemplary features of Western quality. Housing of rugged, stress-relieved construction encasing both pinion stand and reduction gears, means substantial savings in installation costs and mill floor space.



Finished 2-high pinion stand

Engineering Facts

24" center distance—2-high pinion stand
1750 HP at 60 RPM
Reversing service for blooming mill duty
Shipping weight—34,000 lbs.

Western Gear experience in the steel industry can prove invaluable to *your* special needs or mill production problems. For full information, write, wire or phone: **WESTERN GEAR CORPORATION**, Industrial Products Division, P.O. Box 126, Belmont, California—LYtel 3-7611

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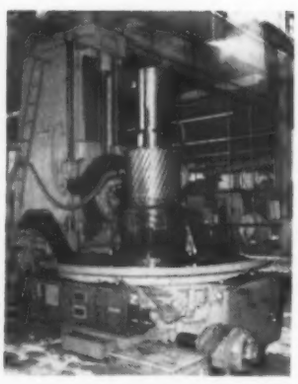
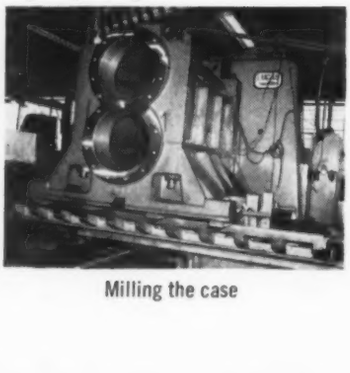


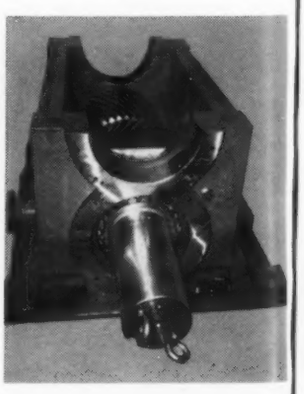
Hobbing the pinion gear



Milling the case

Lower case assembly view

Inspecting gear finishes



inder is integrally mounted and anchored to the axle casting. The entire self-contained axle assembly can be removed from the truck in minutes for inspection and service.

EPOXY-METAL COMPOUND

△ Development of a versatile super-strength epoxy-metal compound specially designed to fill, bond, and repair steel, iron, aluminum, bronze, brass, lead, tiles, concrete, brick, marble, ceramics, porcelain, wood, glass, leather, fabrics and most hard plastics has been announced by the Consumer Products Department of The Borden Chemical Co.

The compound works equally well in repairing dents in sheet metal, defects in metal castings and patterns; caulking metal seams in casements, ducts and tanks; anchoring bolts and screws; and as a covering for countersunk bolt and rivet heads.

The new product is a two-part system consisting of metal-filled resin and hardener. Available in half-pint, pint, quart, gallon and larger size units, each unit consists of a can of metal-filled epoxy resin and a can of hardener which mixes to double the amount of the unit size.

The compound is resistant to most acids and alkalies, is completely waterproof and oilproof, and can be machined, filed, sanded, drilled or tapped. The product sets in two to four hours at room temperatures and cures overnight. Shrinkage is negligible when the compound is used as a filler or sealer. Shelf life is rated as "indefinite." Clamping of joined surfaces is not necessary. The compound cures to a metallic grey color.

FURNACE ROLL COATING

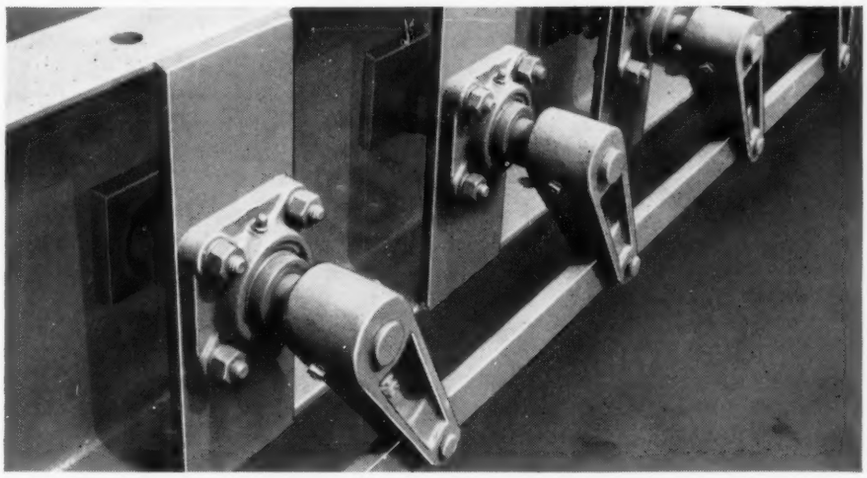
△ A new type of coating for annealing furnace rolls, developed to eliminate a pickup problem, has been introduced by The Duraloy Co. With an extremely hard coating applied at temperatures approaching 15,000 F, Duralize 505 furnace rolls are said to produce much longer service before refinishing, compared with plain alloy rolls.

The rolls are centrifugally cast high alloy steel, available either in solid or sleeve types. Although the

CUSTOM-DESIGNED

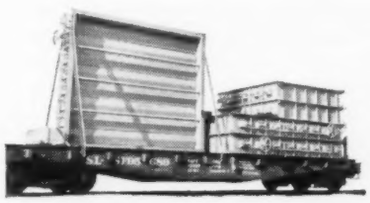
WHIRLEX DAMPERS

FOR POSITIVE DRAFT CONTROL



Whirlex multi-louvered dampers give positive control of your draft problems. Whatever your requirements, Whirlex dampers are custom-engineered, in both louvered and opposed-blade designs, for all types and sizes of applications. And, whether in difficult conditions requiring gas-tight seals and closure strips, or linkages for operating with combustion control equipment, or dust-seal equipped bearings for pressure systems, Whirlex offers equipment *custom designed* to meet your needs.

Whirlex all-welded dampers are completely intergrated and shop-assembled. They assure you of quality controlled, high-efficiency equipment with a consistently low operating and maintenance cost.



Remember, when Whirlex multi-louvered dampers work for you, you get the *best* draft control for the *least* cost. Ask for bulletin #DA-16

THE FLY ASH ARRESTOR CORP

205 North 1st Street / Birmingham, Alabama

1355 Market Street, San Francisco 3, Calif. — 420 Lexington Avenue, New York 17, N.Y.

Bag Collectors — Mechanical Collectors — Wet Collectors
Induced Draft Fans — Forced Draft Fans — Exhaust Fans
Self Supporting Stacks — Duct Work

sapphire-hard coating is relatively thin, it is unaffected by the elevated temperatures to which this coating is subjected.

According to the manufacturer, this new type of roll was developed to resolve a pickup problem common in the annealing of silicon strip. Pickup, which occurs because the furnace roll material has an affinity for the strip being processed, is undesirable because the spikes tend to cause indentations in the strip being processed. Periodically rolls must be reworked to remove spikes.

The rolls have produced service life of several months without refinishing, compared with as short a time as a few hours for plain alloy rolls or other types of coated rolls.

ROTATING CRANE HOOK

△ A motorized rotating crane hook is adding to the versatility of crane operations in the hot coil storage shop of the Butler, Pa., works of Armco Steel Corp.

Suspended from the 20-ton overhead crane that serves the shop, the rotating hook permits objects lifted to be rotated horizontally to any desired direction while being held in the air.

Normally the motorized hook, designed and manufactured by the Materials Handling Division of Heppenstall Co., is used in lifting and rotating coils of strip steel, with the aid of a double "C" hook. In this way, two coils at a time can be picked up, carried to another part of the shop, rotated if necessary, and set down where desired, almost as quickly as the crane itself can move. All operations are controlled by the craneman from his cab.

The hook also is suitable for other kinds of lifting in the shop, up to its capacity of 40,000 lb.

Because of the rotating feature, there is no need for floormen to turn a load, or to "nudge" a load against a column to turn it. A built-in protective device prevents heavy shocks from being transmitted to the motor and drive. The drive is inherently balanced, with no counterbalancing required.

The motorized rotating hooks are available in capacities ranging from 4000 to 150,000 lb.

View from crane cab as two coils of strip steel are lifted and rotated. Motorized rotating hook permits the double "C" hook, carrying the coils, to be rotated horizontally to any direction while in the air. All operations are under the control of the craneman.

New Hawk 401 Utiliscope

An Unprecedented Closed Circuit

Impressed by the potential value of closed circuit television but *depressed* by reports of high initial cost, expensive maintenance, constant requirement for difficult adjustments, and general unreliability? Then listen . . . to an unprecedented proposition from the world's oldest manufacturer of industrial closed circuit television: Indoor or outdoors, in any kind of weather with practically any degree of illumination, Diamond Electronics' all new Hawk 401 Utiliscope is *guaranteed on a money-back basis* to provide a sharp, clear picture of just about anything . . . perimeter barriers, gates, transfer points, loading docks, construction areas, vehicular movement, rooftops, hazardous areas . . . all from one safe, comfortable and convenient location. The Hawk requires no special housing, no special power supply, no special adjustments for changing light and weather conditions. Just plug it into an ordinary 110 V outlet and forget about it.

See for yourself. Call, write or wire and we'll arrange a demonstration within the week.

Diamond Electronics

Division of Diamond Power Specialty Corporation • Lancaster, Ohio

RACK-MODEL RECORDER

△ ElectroniK 15 strip chart recorders produced by Minneapolis-Honeywell Regulator Co. are being made available in 13 standard relay rack models with new speed chart changers and new recording and operating pens.

The rack-mounted recorders are identical electronically and in performance with corresponding models for surface and flush mounting. Cases have been changed, however, and some components rearranged.

Most standard options will be available for relay rack instruments, including a chart speed changer which permits selection of a slow speed for normal operation or a faster speed where greater degree of resolution and record definition are required.

Four standard step-down ratios of 6:1, 10:1, 30:1 and 60:1 are available for single record instruments. On multi-record instruments, a 6:1 ratio is available for 4.5-sec cyclic printing recorders, including Universal models.

Two-pen recorders are equipped with jewel-tipped capillary "forward-writing" pens designed to control bleeding on retracing records at slow chart speeds, minimize skipping at high speeds and increase record visibility. The ink reservoir, isolated from the pen carriage, is connected by capillary tubing to the ink supply. The assembly is standard for all extended range and duplex recorders.

Operation pen assembly has been modified to write on the same time line as the new recording pens.

permits...

Proposition In Television...

POTENTIOMETERS

△ Three new, low-cost, portable potentiometers have been announced by Leeds & Northrup Co. These instruments provide on-the-spot measurements of temperature for instrument maintenance departments, and in testing and research work.

The 8694 Single-Range and the 8695 Double-Range Temperature Potentiometers indicate temperatures directly in degrees F in any of 15 temperature ranges. The 8696 Double-Range Millivolt Potentiometer is calibrated for emf measurements on two ranges, 0 to 22 and 20 to 64, and has a manual reference junction compensation dial. It can be used as a source of calibrated voltage for checking other potentiometer-type instruments.

All three instruments have a basic accuracy of ± 0.3 per cent of range and have a pointer galvanometer with a sensitivity of 0.6 mu a per scale division. Designed to withstand rugged operation, they are compact in size—only 7 in. x 6 in. x 5 in.—and weigh only 4½ lb. Each is housed in a sturdy metal case with a durable gray vinyl finish.

CENTRIFUGAL SWITCH

△ A new Synchro-Snap centrifugal switch with negligible friction to provide repetitive accuracy has been introduced by the EC&M Division of Square D Co. Developed to replace existing centrifugal switches—which depend on complicated frictional relationships between weights,

Another Test System at work...

Push-button actuation conveys billets into test unit, transfers them to magnetization and Magnaglo bath station and on to black light viewing area. A novel device rotates them so operators see all four sides. As one billet leaves, another is ready for viewing; testing is nearly continuous.

Testing 4 Half-Ton Billets a Minute

...with Fully Automatic Handling System Engineered and Built by Magnaflux

This latest Magnaglo billet testing unit for seam detection, clearly differentiates between areas needing conditioning and those that do not. This can avoid costly total skinning or peeling; reduce tonnage losses; cut costs; boost output per poured ton. It processes 2⅝" to 4⅛" square billets in lengths to 34'. A single control button actuation programs the entire sequence.

This unit typifies many Magnaflux designed and built testing-handling systems for square billets and tube rounds, and seamless and welded tubing. All are improving quality control, increasing output, and reducing costs. If these advantages and our experience in test-handling design are of interest to you, phone your local Magnaflux Field Engineer or write to Magnaflux Corporation, 7332 W. Lawrence Ave., Chicago 31, Ill.

MAGNAFLUX CORPORATION
TEST SYSTEMS

A SUBSIDIARY OF GENERAL MILLS

MAGNETIC PARTICLE • FLUORESCENT PENETRANT • ULTRASONIC
EDDY CURRENT • STRESS ANALYSIS • RADIOGRAPHY
DYE PENETRANT • MAGNETIC FIELD MEASURE • THERMOGRAPHIC

bearings, bearing shafts and coil springs—the new switch can be used for speed sensing, overspeed and underspeed detection, speed interlocking, sequencing and signaling.

The switch utilizes a simple one-piece spring steel disk with weights fastened directly to the disk. The centrifugal force of the weights overcomes the rapid decrease in spring force, resulting in a snap action at the operating speed. Normal operating speeds range from 900 to 4000 rpm and standard units operate at 1100 and 2200 rpm. Operating speed is factory-adjusted.

Synchro-Snap centrifugal switches are furnished in dust-proof enclosures and industrial-type snap switches are used.

LIMIT SWITCHES

△ Cutler-Hammer, Inc. has announced the addition of new operators and optional features to its line of Type L precision oil tight limit switches which provide extensive depth and flexible of application.

Nine new Type L limit switch operators and switches consist of: roller lever with metal roller; roller lever with 1-in. wide roller; adjustable roller lever with 1½-in. diam. roller; adjustable spring rod actuator; adjustable nylon rod actuator; duplex limit switch; wobble stick with 12-in. wire extension; cat whisker operator; and precision adjusted roller lever available with either a metal or a nylon roller.

Five new features have also been added to the Type L limit switch line as selected options. These are: manifold style mounting; "Joy" receptacle, mounted and wired; "wet" limit switch; mounting adaptor kits; and oil tight conduit bushings.

PLASTIC FIRE BRICK

△ A new, 90 per cent alumina refractory plastic fire brick is now available from Kaiser Refractories & Chemicals Division, Kaiser Aluminum & Chemical Corp.

Called Mono 90, the product is a companion product to other high alumina plastics, Mono 60 (air and heat setting) and Mono 70 (air setting) in the Kaiser Refractories line.

The outstanding characteristic of Mono 90 is its high fusion point which resists the fluxing action of mill scale. The basis for this mix is tabular alumina, a dense pure highly stabilized aluminum oxide. It is highly resistant to penetration or adherence of metal, facilitating cleaning operations. A characteristic slight expansion in the 2550 F. temperature range assures a tight lining at elevated and operating temperatures.

The plastic fire brick is packaged in convenient 100-lb cartons. It is wrapped in a polyethylene plastic wrapper to provide maximum storage life.

Mono 90 is particularly suitable for use in furnaces using high temperatures and requiring a refractory lining with a high degree of erosion or abrasion resistance. Among the furnaces for which Mono 90 is particularly suited are rotary hearth furnaces, forge heating furnaces and reheat furnaces. It is also designed for use in crucible covers, ladles and soaking pits.

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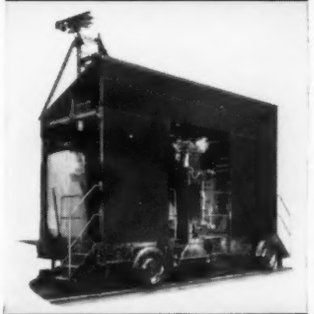
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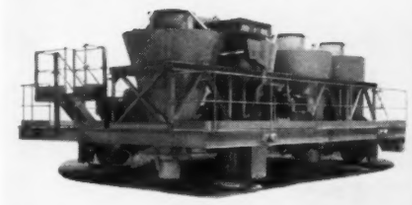
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SWITCH AND FUSE UNITS

△Newly-designed stationary housed switch and fuse equipment which provides low cost short-current protection in electric power systems is now available from the General Electric Co.'s Medium Voltage Switchgear Department.

The new equipment will protect distribution feeder circuits, load center unit substations, lighting and small power transformers for commercial, industrial and electric utility applications.

Four basic stationary housed switch and fuse equipment designs cover a full range of applications and provide for easy future expansion. Available in 5 kv and 15 kv indoor and outdoor frame sizes, the new equipment is rated from 2.4 to 15 kv.

Switch and fuses are housed in either indoor or outdoor structures, together with power fuses, buses, connections, instrument transformers, metering and indicating devices as needed. Design adaptability allows cable entrances, control transformers and lightning arresters to be located above or below the switch.

Both indoor and outdoor assemblies can be installed singly or in line-ups of two or more units, with or without a common bus.

New equipment is furnished with fuses for applications up to and including 400-amp continuous current; without fuses, it will interrupt 800 amp at 2.4 kv and 600 amp up to 15 kv.

Book Reviews

"ASM Review of Metal Literature, 1960," Volume 17, June, 1961 edited by Marjorie R. Hyslop has been published recently by the American Society for Metals, Metals Park, Ohio. The book contains 1342 pages, 6 x 9 in., is cloth bound, and sells for $25. The book contains 11,903 annotations of articles, technical papers, reports and documents appearing in engineering, scientific and industrial journals and books throughout the world during 1960. It is divided into 20 sections covering different areas of materials and process engineering and technology, and includes addresses of publications as well as comprehensive subject and author indexes. (Back issues of Volumes 1 through 16, 1944–1959, are also available at $20 per copy.)

"Mechanical Behavior of Materials at Elevated Temperatures," edited by John E. Dorn, has been published recently by McGraw-Hill Book Co., 330 West 42nd St., New York 36, N. Y. The book contains 529 pages, 6 x 9 in., is cloth bound, and sells for $14.50. Fifteen authors have contributed to this work. This book is aimed at giving a systematic background in dislocation theory and its application to creep and related high temperature properties. It presents chapters on the nature and behavior of dislocations, the use of thermodynamics and statistical mechanics for developing the basic concepts of dislocation stresses for creep, and discusses theories for fracture and fatigue. Correlation between theory and experiment is stressed to provide a basis for understanding the behavior of materials to facilitate design. Chapters on creep and stress rupture under combined stresses, variable conditions of stresses and temperatures, the effects of thermal stresses and thermal shock as well as high temperature fatigue have been included to provide a broad picture of the mechanical behavior of materials at elevated temperatures. Many illustrations—photographs, equations, charts, graphs, etc., have been used to complete and explain the text.

"Response of Metals to High Velocity Deformation," Volume 9, Metallurgical Society Conference, edited by P. G. Shewmon and F. V. Zackay, has been published recently by Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, N. Y. The book contains 491 pages, 6 x 9 in., is cloth bound and sells for $18.00. This is the proceedings of a technical conference sponsored by the Physical Metallurgy Committee of the Institute of Metals Div., The Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers, at Estes Park, Colo., July 11 and 12, 1960. The book contains 16 papers by 27 authors, six on the subject of high velocity deformation and ten on shock phenomena in metals. A subject index is included. The papers are well illustrated, using tables, charts, line drawings, photographs, and equations. Many references are cited.

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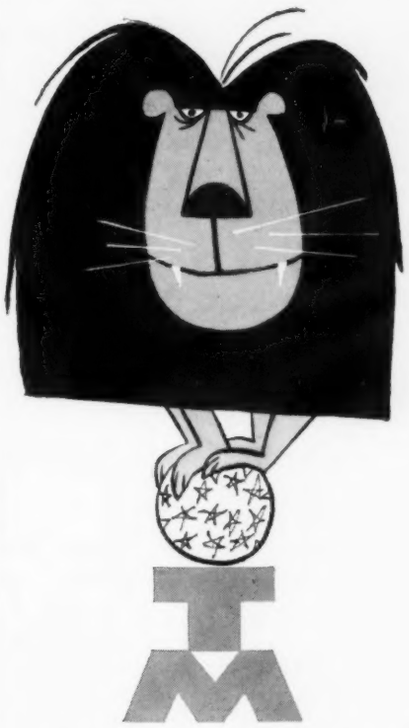

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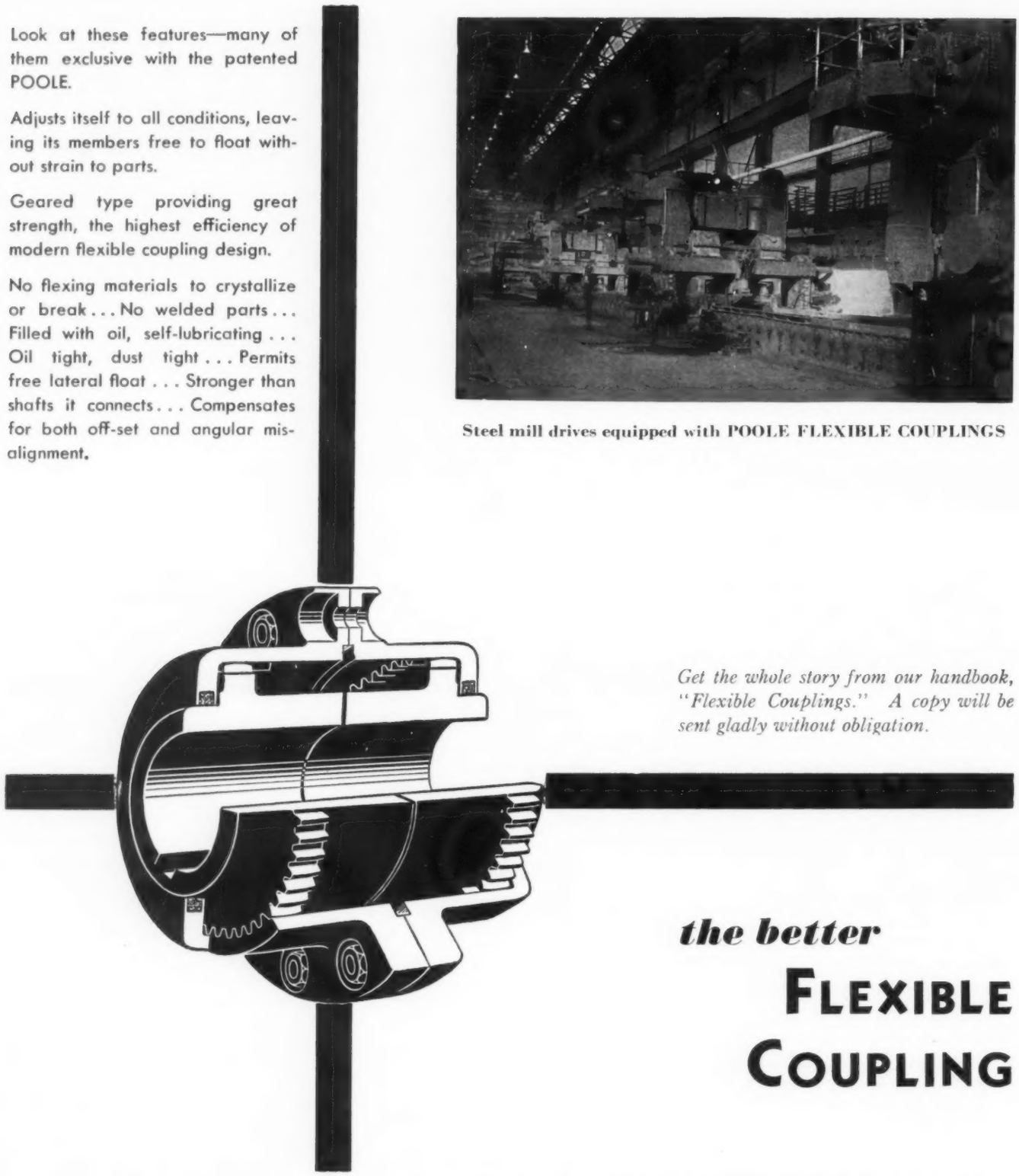

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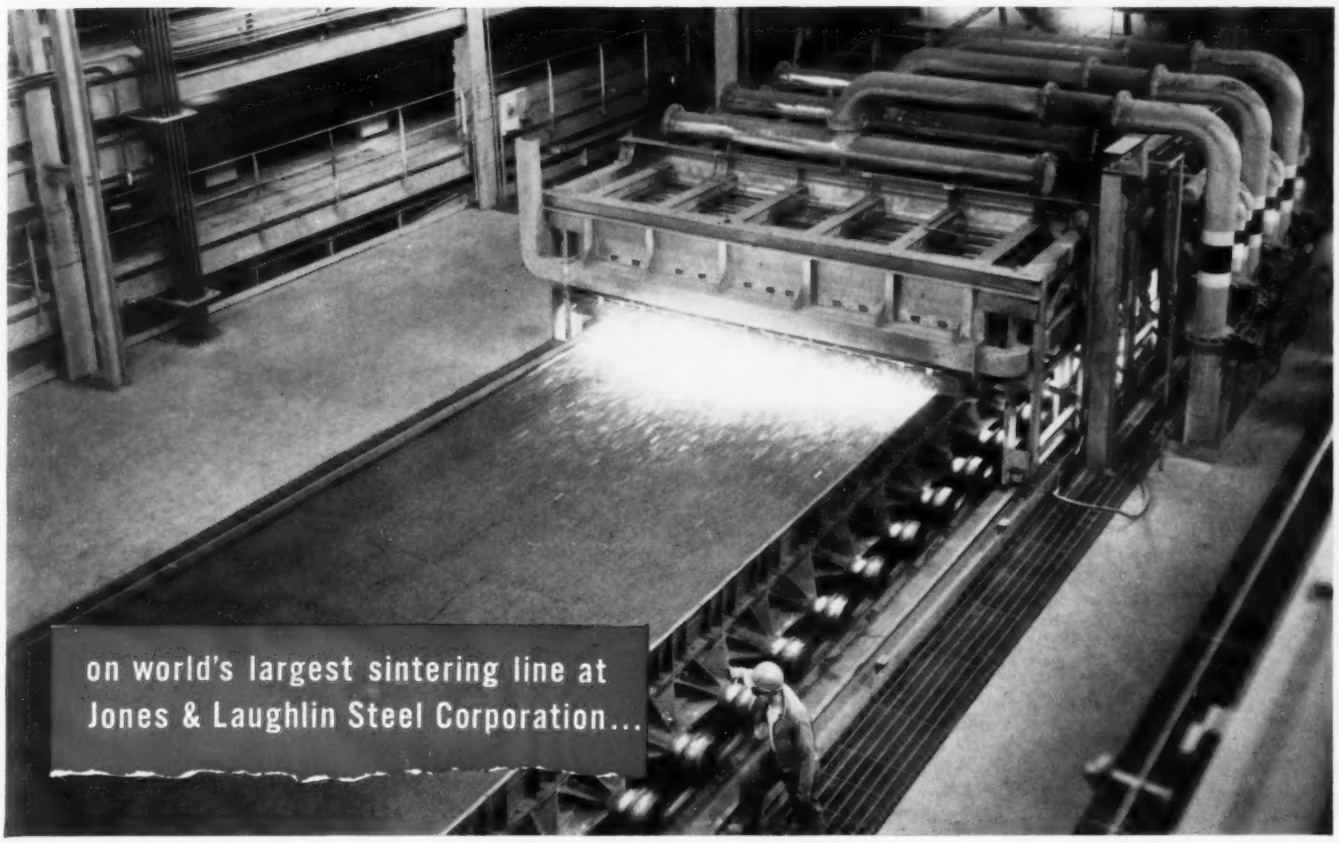

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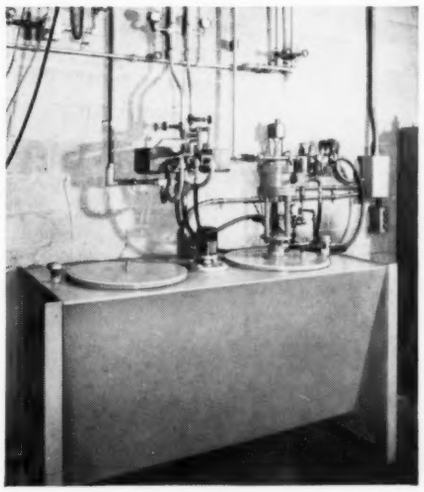

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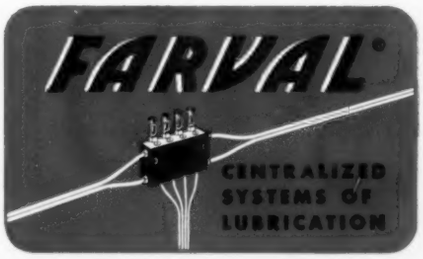

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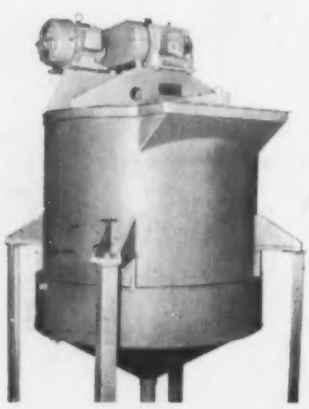
Hot patching with H-W GUNSHOT
faster ■ easier ■ saves time and labor



H-W GUNSHOT MIXER

Hot patching basic open hearths with H-W GUNSHOT helps you get more mileage out of good brickwork and reduces furnace downtime. It's simple and easy to apply and labor time and costs are less. Result: substantial savings in terms of refractory costs per ton of steel produced.

H-W GUNSHOT is available in various compositions. A special mixer and gun are used for gradual and even application of GUNSHOT along the back wall, port skews, front wall, uptakes and roof. Harbison-Walker technical service engineers are available to help you get a GUNSHOT maintenance program started in your shop. Ask for details.

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